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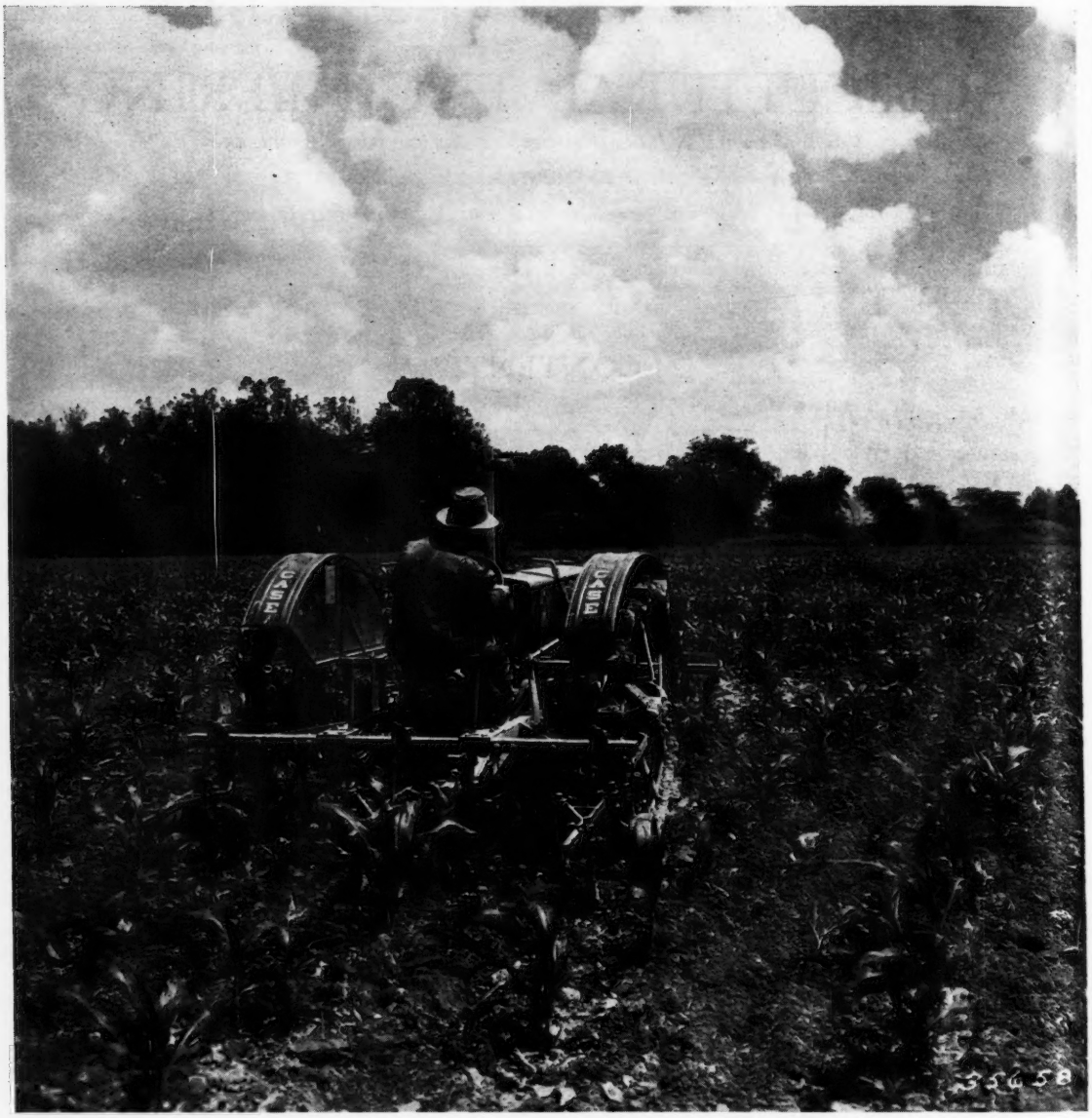

Engineering in Corn Fields

HYBRID CORN is a comparatively new biologic material available to farmers. It marks a step of progress in controlled plant inheritance. It challenges agricultural engineers to match its favorable inherent capacities with equally favorable environment for its growth, fiber development, chemical production, pest resistance, and economical handling.

Crop plant environment includes the physical properties of the soil in which it roots, the chemical constituents of the soil solution, air temperature and humidity, light intensity, and helpful or competing organisms. The chemical, structural, and energy relationships of plant environment, as influences on plant growth, are fields of science. They are basic sciences for mastery and application by agricultural engineers. As natural phenomena within the accepted range of engineering subject matter they are a part of the engineering existing in agriculture, awaiting development. Without basing their work on these phenomena, agricultural engineers can do little more for crop production than to implement the superficial alchemy of common cultural practices. The fact that Indian squaws hoed corn, and that modern farmers still do so with improved hoes, gives no quantitative measure of the soil conditions which may provide an ideal root environment for the productivity expected of corn, and little or no indication of how such soil conditions might most effectively be approximated in farm practice.

Implementing common farm practices and functions was a starting point for agricultural engineers. It gave farmers immediate help and gave engineers a foothold in a logical field for a new branch of engineering. Agricultural engineering now seems to be working down to the more fundamental approach of checking the technical validity of the farm operations and functions to be implemented. That is one big job of engineering in cornfields, and elsewhere on farms.

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Increasing Industrial Use of Farm Products

REFERRING to "field research and engineering" as "the missing link" in the current program for increased industrial use of farm products, D. Howard Doane, in addressing the recent Mid-American Chemurgic Conference, cited some agricultural engineering problems to be solved before investors can safely be advised to carry new technical possibilities into commercial practice.

Mr. Doane used, as an example, the technical possibility of producing starch from sweet potatoes. Years have passed since the laboratory technique was worked out, and a pilot plant has been in operation for several years. Certain questions influencing the profit possibilities of commercial operation, however, have not been worked out.

What percentage of the farm labor of growing sweet potatoes for starch must be used in hand operations, and what percentage can be applied through machines? What machines not now available should be created to cheapen farm cost of production? Will it be best to encourage and intensify present methods of production, or do they all need overhauling? When the best known methods are used, are production costs well or poorly balanced as to capital and current outlay? Does sweet potato production fit best into small or large farm units? It all seems to boil down to this. In what ways and to what extent can control over environmental conditions during growing, harvesting, handling, farm storage, and transportation influence quantity, quality, and cost of starch production? To what extent could initial processing be carried on by farmers or in farm community plants? And what would be an efficient equipment and operating setup to carry out the necessary or desirable farm operations?

These are not all of Mr. Doane's questions, and this is not the only crop, product, or industrial use to which they apply. However, they may help to orient agricultural engineers and the interested public as to the logical place of agricultural engineers in furthering the industrial use of farm products.

Functional Planning

CAN standard farm building plan services be reconciled with functional planning to meet individual requirements? The question is brought up by a brief paper which R. H. Driftmier presented at the last meeting of the Southern Section of the American Society of Agricultural Engineers.

Standard plan services recognize the inability of the ordinary farm to justify individual architectural service. They also recognize geographic area and farm type requirements in general.

Functional planning recognizes individual and community differences in building requirements, based on land use, production programs, market opportunities, and personal factors.

Standard plan services are pointed toward structural and architectural improvement at minimum cost, while functional planning aims at maximum use value.

Presumably some measure of off-hand functional planning is practiced by any and every farmer in arriving at a decision to invest money in building improvements. The extent to which agricultural engineers might be justified in amplifying such planning in the direction of detailed engineering analysis would seem to depend on the scale of farm operations and investment involved and the degree of improvement in results which might be obtained, considering agricultural engineering proficiency in this field, the availability of basic data essential to accurate analysis, and the extent to which the farmer will follow resulting recommendations.

Two possibilities occur to us for reconciling or combining these types of planning to obtain some of the advantages of both. One is to work out and give farmers a digest of principles to follow in doing their own functional planning as a basis for selection and utilization of standard plans. The other is to obtain from farmers the necessary data on their farms, operations, and conditions, and let agricultural engineers do the major part of the functional planning on which to base standard plan recommendations. Probably individual differences between farmers would determine which way would give the best results in individual cases.

Or possibly neither of these suggestions is the solution of the problem. At any rate, the implied opportunity for increasing the effectiveness of farm structures extension work seems worthy of considerable thought.

Patent Data Wanted

AGRICULTURAL engineers who have had one or more patents issued to them since 1921, will be interested in contributing to the joint patent inquiry now in progress by the National Association of Manufacturers, the National Industrial Conference Board, and American Engineering Council.

There has been considerable pressure in recent years for substantial changes in the patent law of the United States. To what extent is this pressure exerted by uninformed reformers, and to what extent is it exerted by men and industries active in patent matters and concerned with effective administration of the constitutional intent and spirit of patent rights as a stimulant to scientific, economic, and social progress? What changes, if any, will increase the effectiveness with which the intent of patent law can be carried out in the interest of the public? Are the interests of the public, of inventors, and of manufacturers in patent matters substantially identical or conflicting? The answers to these questions need to be brought to light and to the attention of Congress, if the patent system is to be made more workable in the public interest and not become a battleground for class struggle.

A part of the inquiry into the operations of present patent law is a questionnaire to inventors. Inventors who are members of engineering societies have been requested to cooperate in answering the questionnaire, copies of which are obtainable from American Engineering Council, 744 Jackson Place, Washington, D. C.

Information called for on the questionnaire includes patents issued to the individual, manner of use, reasons for nonuse, opposition encountered, litigations involved, cases of validity sustained, applications denied, rewards or satisfactions other than monetary, and professional connections of the inventor. This information is wanted immediately.

Misfit Mechanical Teams

INCREASES in the range of sizes, types, and makes of tractors and of tractor-operated equipment are forcing the issue of further standardization of power take-offs, drawbar hitches, tractor seat locations, and belt pulley speeds.

Designs based largely on manufacturing considerations, and on the engineering of complete lines for matching driving and driven equipment within individual lines, have not solved the problem. Farmers will buy one make of combine, and another make of plow, corn picker, or hammer mill, and expect to operate each with still another make of tractor.

Farmers buy one make of tractor and other makes of operated equipment to secure real or imagined advantages of the individual unit for their particular conditions, and for a number of other reasons unrelated to the effectiveness with which the individual unit matches the other equipment with which it is expected to work. That detail is often unforseen or taken for granted by the farmer until he has purchased the equipment and started to use it. Then he spends a day or a week waiting for the local blacksmith or the dealer's or manufacturer's service man to hitch up his misfit mechanical team. The fact that manufacturers match their equipment units carefully in tooling up for production is no basis for any assumption that most farmers will do the same.

This headache for farmers and for manufacturers' service departments seems likely to continue, and to have an adverse effect on farm equipment sales and use, until some basis for interchangeability is reached and put into practice.

One well-considered suggestion from the industry is that some neutral party prepare a paper on operating or functional considerations, as a starting point for agreement. Presumably the primary objective of connecting tractor power to any operated unit is to operate that equipment at somewhere near its maximum efficiency in any and all of the work and conditions it is made to handle. A related consideration is safety of the operator. Casualties cut down efficiency and directly defeat the social and economic objectives of machine operation. A third operating consideration is ease and speed of connecting and disconnecting the tractor from the operated equipment.

If any degree of interchangeability of different lines of tractors and operated equipment is to be achieved without the trouble, expense, and inefficiency of special connections, some degree of uniformity of the connecting members must be reached. This applies to mechanical form and size, point of location, and rotative speeds.

In other words, tractor and equipment engineers need certain relatively fixed points on which to base their designs. They need a hitch form and point which will be satisfactory from the standpoints of clearance, maneuverability, machine efficiency, and ease of connecting and disconnecting. The same considerations of form and location apply to the power take-off, and, in addition, a common rotative speed in relation to ground speed, as a basis for design to provide proper functional speeds of moving parts. In the case of belt pulleys, belt speed in relation to power development and power requirements might be a point of possible agreement. Tractor seat location is the point to which the equipment designer must work in providing levers to be operated conveniently from the seat. And uniformity of location, form, size, and clearance of these parts is the limiting factor in providing proper safety guards on a low-cost, quantity-production basis.

We do not presume to say what sizes, mechanical forms, locations, or speeds might be most suitable from either an operating or a manufacturing standpoint, or to have otherwise exhausted the subject. We merely call attention to the importance, difficulties, and angles of the problem, and to the public service, farm, and industrial interests involved. Agricultural engineers in public service might contribute suggestions as to desirable features from an operating standpoint, and agricultural engineers in the industries consider means of providing them, from the standpoint of practical manufacturing possibilities.

One Hundred Hours of Opportunity

WITH apologies to the forty-hour week, the A.S.A.E. annual meeting at St. Paul this month offers one hundred hours of opportunity in a little more than four days. It is opportunity for the individual agricultural engineer to meet and associate with any of several hundred of his contemporaries, in the combined atmosphere of an A.S.A.E. meeting, a college campus, a well-rounded college agricultural engineering department, two large northwestern cities, the "breadbasket" agricultural region, and the recreational area of the "ten thousand lakes." A large selection of optional activities has been provided to enable each individual to make the most of his hundred hours at the meeting, according to his requirements and tastes.

General, technical, and group sessions are scheduled for about one-fourth of the time, with as many as four technical sessions in progress at once. Ten hours of special entertainment for the group have been scheduled, in addition to the ladies' program. Inspection trips will absorb another few hours for those interested. Probably all but the hardiest of the young student members attending will want to sleep through anywhere from twenty to thirty of their hours in St. Paul. And the balance, around thirty hours, is unscheduled time left entirely to the discretion of the individuals attending. Experience has indicated that it is well used and appreciated for committee meetings, informal contacts, sociability, and general listening in on the grapevine broadcast of advance information.

The program practically speaks for itself, but might be summarized approximately with the fact that it schedules more than one hundred speakers and discussers in twenty-eight sessions with more than eighty subjects selected for apparent importance, timeliness, and breadth of interest. These are tangible rallying points for the meeting of minds and exchange of information and viewpoints. The schedule shows where and when individuals may expect to find concentrations of people, information, and thought on subjects of common interest. It continually offers new lines of thought and subject matter to steer the meeting away from one-track tendencies.

Agricultural engineers come together at their annual meeting in an approachable mood, with the time and disposition to talk with anyone on any subject of technical or professional interest. Facilities are provided to encourage maximum free interchange of information and ideas. The program is elastic enough to fit varying individual requirements like the skin on a sausage.

In brief, if you can attend the annual meeting, its one hundred hours of opportunity are yours. You can make the most of them by taking the initiative in meeting people you want to talk to; being present at the scheduled time and place of papers you want to hear, taking part in discussions on subjects of interest to you, and seeing the things you want to see. Then it will not end on Thursday afternoon; its influences will live on in your life, work, and opportunities. You can make it a great meeting for you.

Improvement of Disk Tools

By A. W. Clyde

McKIBBEN[1] has discussed several of the principles involved in disk harrows, and Sjogren[2] has given the difficulties and progress with the offset disk. Progress with all disk tools has been handicapped, however, by lack of information on the soil reaction which the disks encounter. This is of vital importance because in usual operation the soil reaction, the pull, and the weight are in equilibrium and one cannot be changed without a change in at least one other.

Two previous reports by the author[3,4] gave information about the soil resistance encountered by an 18-in disk harrow gang, a self-aligning disk jointer, and a 24-in disk plow. Suggestions were also given for using the data in computing bearing loads. The tests reported, however, covered only a limited number of tool sizes, angles, loadings, depths of penetration, and soil conditions. To get fuller information as to the effect of these factors on the design and operation of disk tools, tests have since been made as follows:

1 18-in disks, 1¾-in concavity, 24-in radius, 6⅝-in spacing, upright position

2 22-in disks, 2½-in concavity, 25⅞-in radius, 9-in spacing, upright position

3 24-in wheatland disks, 3⅝-in concavity, 21⅝-in radius, 8½-in spacing, upright position

4 24-in disk plow, 3⅜-in concavity, 23⅛-in radius, tilted 21 deg backward at top

5 Offset disk harrow having twenty 22-in diameter disks with 9-in spacing

Presented before the Power and Machinery Division at the fall meeting of the American Society of Agricultural Engineers, at Chicago, Ill., November 29, 1938. Authorized for publication on November 28, 1938, as paper No. 865 in the journal series of the Pennsylvania Agricultural Experiment Station. Mr. Clyde (Fellow A.S.A.E.) is professor of agricultural engineering, Pennsylvania State College.

[1] A Study of the Dynamics of the Disk Harrow, E. G. McKibben, AGRICULTURAL ENGINEERING, vol. 7, March 1926..

[2] Development of Offset Disk Harrows, O. W. Sjogren, AGRICULTURAL ENGINEERING, vol. 17, Dec. 1936.

[3] Measurement of Forces on Soil Tillage Tools. AGRICULTURAL ENGINEERING, vol. 17, Jan. 1936.

[4] Load Studies on Tillage Tools, AGRICULTURAL ENGINEERING, vol. 18, March 1937.

FIG. 1. TILLAGE METER WITH GUIDING TRACK AND PEN RECORDER. THE 18-IN DISKS ARE SHOWN MOUNTED WITH VERTICAL FREEDOM

EQUIPMENT

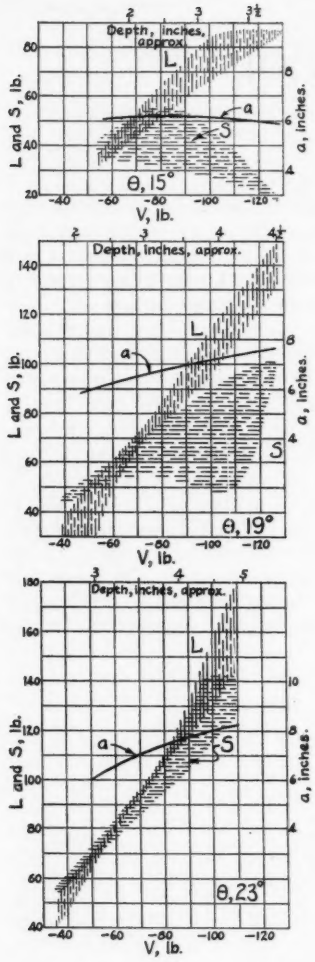
Since the last report the following improvements have been made in the tillage meter: (1) A guiding track 200 ft long has been added to carry the side force and give accurate control of width of cut. It also permits running the main wheels on the original ground surface instead of in the furrow, thus giving much better depth control. Air tires on the main wheels are now ¾ filled with water so that the axle height changes only slightly with changes in loading. (2) Dynamometer pressure cells now have a thinner, more flexible diaphragm, with no fabric reinforcement (Garlock No. 7601), and the bridge washer is now 0.010 in thick. All cells are now preloaded and means have been provided for checking more closely and adjusting the position of the plunger. These improvements give greater accuracy. (3) A pen recorder which makes an ink record of the six pressures on a strip chart is now used. It permits immediate inspection of results and so removes the main drawback of the photographic method used previously. The pressure elements are helical Bourdon tubes commonly used in recording pressure gages.

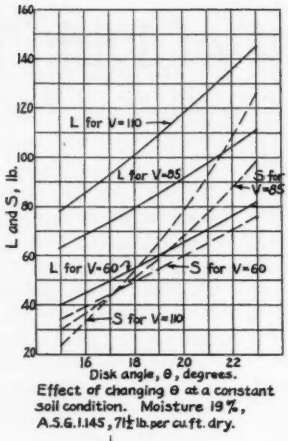
METHODS

The 22 and 24-in disks were attached rigidly to the subframe of the tillage meter, one, two, or three disks being used in order to avoid having to measure very small forces. They were then operated at several depths and angles. Some of the tests of the 18-in disks were made similarly using four or five disks, but most of them were made with the disk assembly mounted with vertical freedom. This permitted the disks to penetrate as deeply as their weight would force them. Various loadings were then obtained either by adding weight to the assembly or by counterbalancing for light loadings. Experience showed, however, that tests at different depths with rigid mounting gave the desired information with less tedious calculation.

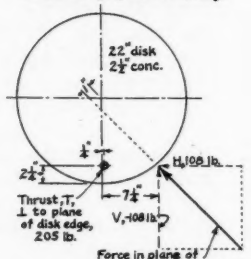
In all tests a speed of approximately 3 mph (miles per hour) was used and the variation from this figure was small.

The variable most difficult to control is the soil. The plot selected for most of the work with 18-in, 22-in, and wheatland disks was Hagerstown silt loam which had been plowed the previous fall. This soil, even at 22 per cent moisture, had practically no tendency to stick to the disks at the speed used. Before being used it was cultivated or disked 4 in deep, smoothed with a peg-tooth harrow or soil packer, and then allowed to stand until compacted by rains. All preparation was done at a considerable angle with the direction of travel in testing, in the belief that this would assist in getting more uniformity of soil. Usually a number of tests were made on a tool in one day and the tests were repeated later when the moisture in the soil had changed. With the 18 and 22-in disks, the tractor was usually operated on the ground worked previously to avoid compacting the soil ahead of the tool. A few tests, however, were made in soil purposely run over by air tires on the tractor, and a few were made in soil just previously disked. This was to have the same condition as encountered by the rear gangs of a tandem disk. Several tests were also made with the wheatland disks in clay loam sod at moisture from 16.8 to 11.4 per cent in the upper 6 in. This was to get a condition where penetration would be





Effect of changing θ at a constant soil condition. Moisture 19%, A.S.G. 1.145, 71½ lb. per cu ft. dry.

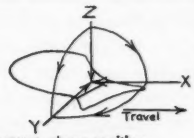


Maximum Test
θ = 23° V = 108 Depth = 5"
L = 179 S = 147 Moisture, 24%
MX = 108 × 8 = 864 inch lb.

Depth of penetration, D, to give appreciable bearing at ground surface on back side. Disks sharpened on back.

θ, degrees	D for 18" disk	D for 22" disk
15	1 1/16"	1½"
17	2	1½
19	2 3/16	2
21	3 1/8	2 1/8
23	3 11/16	3

Soil Force on Tool			Couple or Moment		
Designation	Symbol	Parallel to axis	Axis	Symbol	Positive direction
Longitudinal	L	X	X	MX	Z→Y, clockwise looking ahead
Side	S	Y	Y	MY	Z→X, clockwise looking left
Vertical	V	Z	Z	MZ	X→Y, clockwise looking down



Arrows show positive directions of L, S, V, & couples.

R, resultant of L, S, & V
RH, " " L & S
RV, " " L & V
T, component of R ⊥ to plane of a disk
H, component of R_H in plane of a disk
U, resultant of H & V
θ, horizontal angle between X axis and plane of a disk.

Whenever practicable, L should be the useful soil force on the tool without including parasitic friction on stabilizing surfaces or rolling resistance of wheels.

$a = \frac{MX}{V}$

W, weight
P, pulling force
PX, component of P ∥ to X
PY, " " " Y
PZ, " " " Z
PH, resultant of PX & PY
PV, " " PX & PZ
ASG, apparent specific gravity, dry basis

Fig. 2 (Above) Symbols suggested for general use. They are similar to those used in aerodynamics and give consideration to what have been used with tillage tools. Fig. 4 (Left) Test results with 22-in disks (2½-in concavity) operated at three angles and with various values of $-V$. Soil ranged from 19 to 24 per cent moisture in upper 4 in, except as indicated, and apparent specific gravity 1.143 (71½ lb per cu ft dry). Large values of S occurred with high moisture. A small variation in moisture near the surface made a considerable variation in depth at light loading, but a smaller variation at heavy loading

more difficult than in the field mentioned previously. All tests of the disk plow were made in sod since rather severe conditions were desired. Samples for determination of moisture and apparent specific gravity, or weight per cubic foot, were taken with a tubular sampler 2⅛ in in diameter, the sample being taken from the surface to a depth of 4, 6, or 7 in, as indicated in the results for each tool.

The method of making pulling tests on the complete offset disk harrow will be described later.

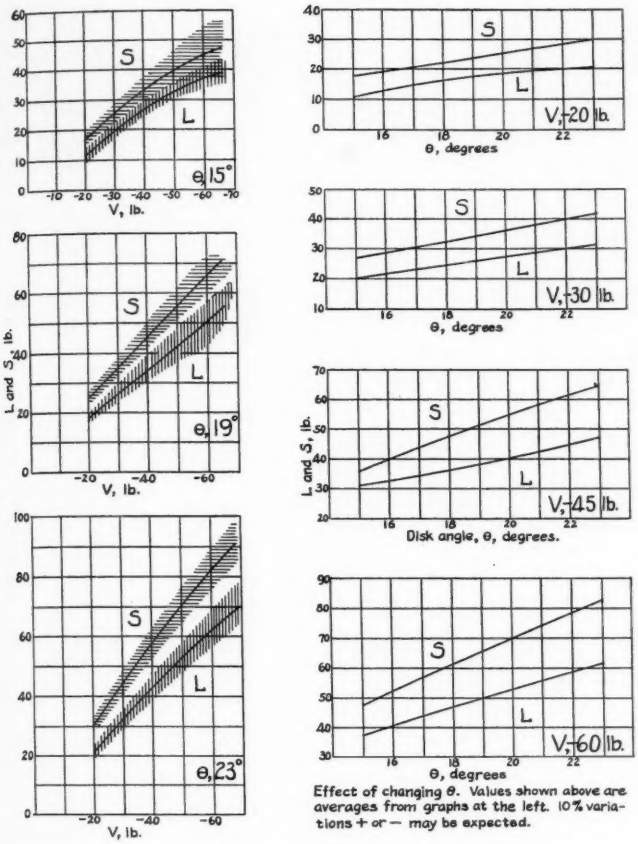
RESULTS AND DISCUSSION

Previous reports have discussed the nature of the soil reaction on tillage tools. Actually the reaction is the sum of infinitely small forces distributed over the contact area. In the case of tools which move soil sideways, this reaction can seldom, if ever, be represented by a single resultant. A rotational tendency exists which can be expressed in either of two general ways, namely, two non-intersecting forces, or a single force and a couple. The couple may be placed in any desired plane provided the force is located to give the certain total effect. In giving the results of tillage tool tests, it is usually most convenient to put the couple in a plane perpendicular to the direction of travel. As shown in Fig. 2, a couple in this plane is designated as MX. All disks tested have had a couple in the soil reaction and, when moving soil to the right, the couple has been positive or clockwise as seen from the rear. Unless otherwise mentioned, all couples mentioned in this report will be positive values of MX.

The vertical soil reaction, V, has always been found upward (negative) on disks used in an upright position. They must be forced down into the ground. With a disk harrow having no supporting wheels, V is numerically equal but opposite in direction to the net weight of the tool carried by the disks when the tool is at work. It must not be confused with the static weight, since the pulling force or a transfer of weight may cause it to be considerably more or less than the static weight, as will be discussed later.

L, S, and V are primarily functions of depth of penetration. Ordinary disk harrows, however, operate at nearly a constant net weight, hence a nearly constant V. This, together with the fact that shallow depths are not measured closely, is the reason for giving L and S as functions of V for 18 and 22-in sizes. The other tools, having wheels, operate at a nearly constant depth, hence L, S, and V are shown as a function of it.

Tests on 18-in Disks. Fig. 3, showing the effect of L and S when V is changed, and the effect of changing Θ, includes tests with soil moisture in the upper 4 in from 14 to 22 per cent, some tests in which the soil was compacted by tractor wheels and a few second-time-over tests. The average weight of a tandem tractor disk is 30 to 35 lb per disk, but the PZ of the rear gang would often make V for



Effect of changing θ. Values shown above are averages from graphs at the left. 10% variations + or − may be expected.

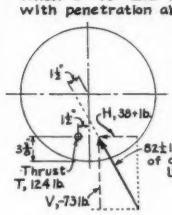
TYPICAL VALUES OF COUPLE, MX, RIGHT HAND DISK.

No. of tests	θ, deg.	V, lb.	MX, inch lb.	$\frac{MX}{V}=a$
5	19⅓	25	70	2.8
7	19	35½	124	3.5
2	19	37½	177*	4.75
2	19½	49	220*	4.5
6	19	51	158	3.1
8	19	66	205	3.1
1	19	73	300	4.1
12	23	44½	117	2.6

* By pulling method.

With exceptions noted, values of L, S & MX given on this sheet were secured with the tillage meter. Previous tests with an 8 or 9 disk gang by the pulling method gave higher values of L. With θ=19 to 22° and V=35 to 50 lb., L was slightly less than S. With V more than 50, L & S were about equal.

Soil — Hagerstown silt loam, 14 to 22% moisture, compacted by rains during about 1 month. Penetration about 2½ in. when θ = 19° and V = 35 lb. A few tests, 2nd time over, with penetration about ¾ in. deeper, are included.



Maximum Test
θ = 23° V=73 Depth = 4½"
L = 84 S=99
MX = 73×4.1 = 300 inch lb.

Fig. 3 Test results with 18-in disks (1¾-in concavity) operated at three angles and with various amounts of net weight or values of $-V$

the rear gang 10 lb less, and for the front gang 10 lb more than this figure. The first group of curves are shown as bands with average values indicated because of the difficulty of showing the effect of all soil variables. In the second group, only the average values are shown. There is some tendency in more firm soil for L to be toward the lower and S toward the higher side of their respective bands, particularly at high values of V. This was very noticeable in some tests on still harder ground which are not included. At heavy loads, in the harder soil, L was considerably lower than shown in Fig. 2, but S was only slightly lower, S being from 40 to 80 per cent more than L. With the soil conditions of Fig. 3, RH usually met the plane of the disk 1 to 2 in back of the vertical center line, and RV met it about 2 in above the bottom.

Tests on 22-in Disks. This tool has an average weight of about 85 lb per disk without extra weight and probably it will often have a V as low as 60 on the rear with 110 on the front. Results on couples are given differently than for 18-in disks. Average values of a are given, which, multiplied by V, equals MX. This is the same a as shown in Fig. 2 of reference (4). In combining forces given by the tillage meter, a is usually measured, then multiplied by V to arrive at MX. It is the lever arm of V about L when L and S are considered concurrent. It has practical use in calculating the best lateral location of the center of gravity. This will be discussed later under "Center of Gravity and Hitching."

A noteworthy feature of these results is the wide spread of values of S at angles of 15 and 19 deg, even though the range of soil conditions was rather small. The explanation of this is probably the amount of side support furnished by the furrow wall. At usual working angles, as a disk is pressed deeper into the ground, a point is reached where it begins to get appreciable bearing on its convex side. This is reached soon if the disk is sharpened on the rear as was true with all disks in this study. See Fig. 4 for measurements of this depth on both 18 and 22-in sizes. If the net weight is enough to cause greater penetration, some of the side force is carried by the furrow wall. This is not measured and is not transmitted to the bearings or frame of the tool. The depth at which this factor becomes noticeable depends upon soil moisture and compactness. A slight change in these seems to make a large change in the ability of the furrow wall to furnish side support. With 18-in disks at 15-deg angle there is some indication of this factor with heavy loading. An important thing, however, is that this loading is beyond the range of usual operation, while with 22-in disks, this factor is very noticeable in the range of customary loading. This factor has practical use with offset disk harrows as will be explained later.

RH usually met the plane of the disk near the vertical center line, and RV met it from 5 to 8 in above the bottom.

For a given depth of penetration, there appears to be little difference in L (or draft) per disk between a 15-deg angle with heavy loading and a greater angle with lighter loading. For example, in one series of tests at a depth of 3½ in, an L of 85 to 88 lb was obtained at 15 deg, $V = -128$; at 19 deg, $V = -85$; and at 23 deg, $V = -63$. In any comparisons of this kind, however, it should be noted that the width of cut is proportional to cos Θ, since the disk spacing on the axle is fixed. The width of cut

decreases as Θ increases, but tillage becomes more thorough because the disk displaces a greater amount of soil. A 22-in disk with 9-in spacing, 3½-in depth and angles of 15, 19, and 23 deg, actually sweeps through only 34, 44, and 54 per cent, respectively, of the gross furrow volume, though additional soil between the disks is usually broken loose. 18-in disks with 6-in spacing at a depth of 3 in sweep through 3 to 4 per cent more volume than the figures given above.

Tests on 24-in Wheatland Disks. Fig. 5 gives results for this tool at three angles and various depths. The flat place on the *S*-38-deg curve is probably due to some accidental cause and might disappear with more tests. The factor of bearing on the rear side of the disk shows very strongly at a disk angle of 30 deg. With the soil condition at which these tests were made the side force was carried entirely by the furrow wall when the depth was about 6⅜ in and operation at greater depth was impossible unless some extra force were provided in the direction of *S*. The large negative value of *V* for the 30-deg disk angle should be noticed. Fig. 5 also shows the location of the forces in the maximum test. This was at a depth of 8 in, at which depth soil was going over the axle and being pushed ahead by it. Results are given in the form of two non-intersecting forces, *RH* and *V*, also with these forces recombined into *T* and *U*. This tool, as manufactured without extra weight, usually weighs from 185 to 200 lb per disk. When an upward *PZ* of about 50 lb is subtracted, there would have been practically no weight remaining to be carried by the wheels. Under this condition it would no doubt be necessary to add weight to keep the furrow wheels from climbing the furrow wall.

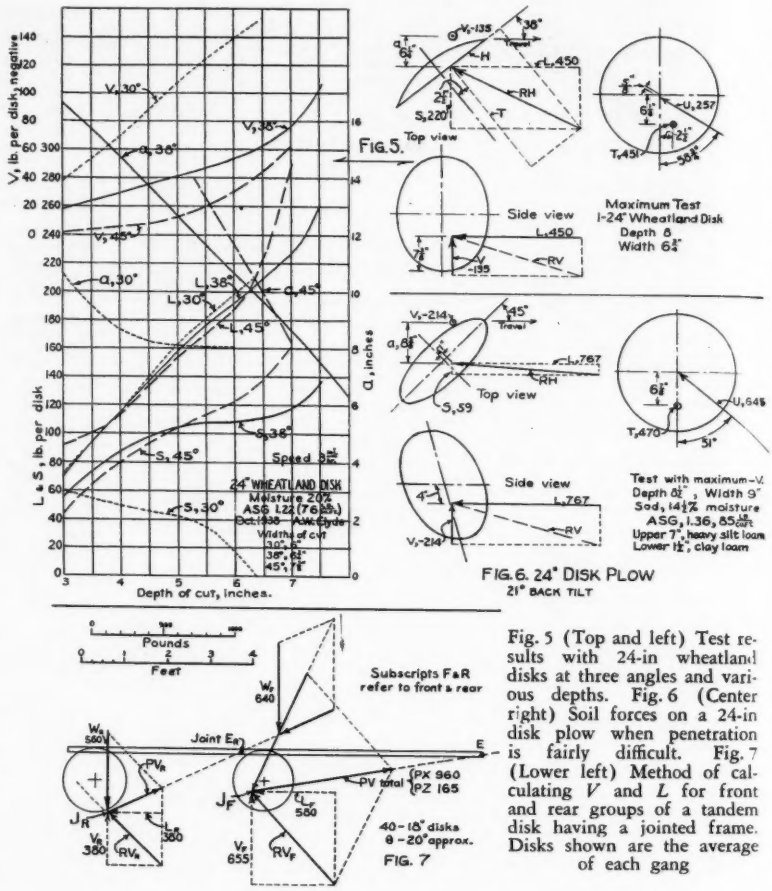


Fig. 5 (Top and left) Test results with 24-in wheatland disks at three angles and various depths. Fig. 6 (Center right) Soil forces on a 24-in disk plow when penetration is fairly difficult. Fig. 7 (Lower left) Method of calculating *V* and *L* for front and rear groups of a tandem disk having a jointed frame. Disks shown are the average of each gang

In an effort to find a condition in which penetration would be more difficult, several tests have been made at a 38-deg angle, 6-in depth in clay loam sod, and apparent specific gravity of 1.325 (82.6 lb per cu ft, dry). Averages of two tests each were as follows:

Moisture (%)	*L*	*S*	*V*	*a* (in)
16.8	275	145	−90	6
15.1	255	130	−87	6¼
12.8	233	120	−88	8¾
11.4	270	138	−115	6¾+

Tests on 24-in Disk Plow. A number of tests have been made since those previously reported in order to learn what happens when the soil is rather dry. Fig. 6 gives the average of four tests with the largest negative values of *V*, or the most difficult penetration. When bearing loads were calculated by the method used in Fig. 6, reference (4), the radial loads on *A* and *B* were about 1860 and 2230 lb respectively, and thrust on *B*, 470 lb. They were nearly horizontal. Since the average depth was 8 in, the furrow was 72 sq in as compared with 86.2 sq in in the earlier report. It appears, therefore, that bearing loads under this condition were practically no greater in proportion to the furrow cross section than they were in more moist soil. Their direction was distinctly different, however. Here again the value of *a*, or location of *V* with reference to *RH*, is useful in locating best lateral position of the center of gravity.

These tests indicate that considerable side force was being carried by the convex side of the disk as tests in more moist ground gave much higher values of *S*. It will be seen that tilting the disk backward assists penetration. *V* had a lower negative value in relation to *L* than the upright disk had in similar soil conditions. With the tilted disk, when the moisture was about 17 per cent or more, *V* was positive or downward. To use a common expression, the disk then had "suction".

APPLICATION OF FINDINGS TO DESIGN AND OPERATION

Tandem Disks in General. Two distinct types of tandem disk harrows are being made, namely,

1 Jointed frame, in which the rear gangs are pulled from a joint on the front gangs, the joint permitting vertical motion. It is analogous to a cart with one axle pulling a semitrailer with one axle.

2 Rigid frame, in which the frame has no joint between gangs. The drawbar, however, is provided with a joint ahead of the front gangs. It is analogous to a wagon.

Fig. 7 shows the first type, and the method of studying

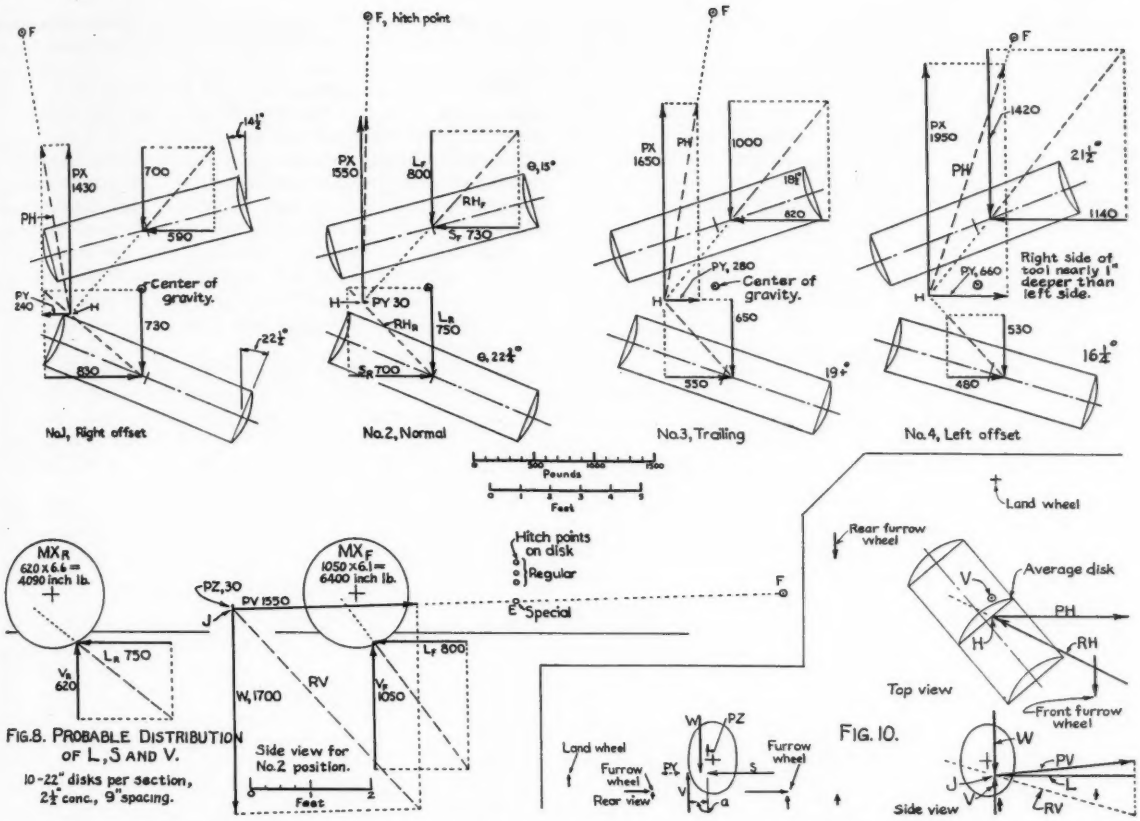


FIG. 8. PROBABLE DISTRIBUTION OF L, S AND V.
10-22" disks per section, 2½" conc., 9" spacing.

FIG. 10.

Fig. 8 Probable distribution of *L*, *S*, and *V* between front and rear gangs of an offset disk. Numbers 1 to 4 are the positions of the tool with four locations of the hitch point *F*. All except one location requires an angled pulling force. Fig. 10 (Lower right) Illustrating the forces acting on a wheatland disk or a disk plow which must be considered in deciding the location and direction of the pulling force and the distribution of weight. Several combinations may be satisfactory

what may happen to the weight distribution. Starting with the rear, we know that its *P* or *PV* passes through the joint *ER*. Knowing the location of *W* and knowing approximately the position of *RV*, we can then locate *PV* and determine *V*, it being the weight less *PZ*, the upward component of pull. (Symbols in this paragraph apply to the rear gangs only.)

Fig. 3 is consulted for the relationship between *V* and *L* (or the slope of *RV*) for any selected disk angle. The front is then treated in the same way except that the pull furnished to the rear must be included. This has been done by combining it with the weight of the front. For a concrete example, assumed values for a 40-disk tool weighing 1200 lb are given. The rather high hitch point *E* assumed in this case gives a total *PZ* of 165 lb. This leaves 1035 lb net weight available for causing penetration, which is divided to 380 lb on the rear and 655 lb on the front. This method, if based on the known characteristics of disks in the soil being worked, should be accurate enough for practical purposes.

Inspection of the drawing shows that if more weight is to be added to increase penetration, it is most effective when added toward the rear of a gang, since that decreases the upward pull on the tool.

The increase of *V* at one point and an equal decrease at another point, caused in this case by the height of the pulling force, is commonly called weight transfer. It may be noted that in this type of frame, the weight transfer is largely built in at the factory by the position of joint *ER*. The operator can modify the weight transfer somewhat by placing the gangs at different angles, but ordinary variations in height of hitch point *E* at the tractor have less effect than the same variation of *E* on a rigid frame. For example, lowering *E* reduces *PZ* and increases *V* of the front gangs by practically the same amount. The rear is practically unaffected because *ER* is changed only slightly.

The rigid frame type of tandem is shown by the lower drawing in Fig. 8. In this tool the hitch extends from joint *E* to the tractor at *F*. A track-type tractor with a low drawbar was used and a special low hitch point was put on the disk to avoid the large weight transfer with the regular hitch points. *E* and *F* locate the pulling force, and *J*, its junction with *W*, together with the known values of *PX* and *W*, are combined to determine *RV* for the entire tool. The next job is to approximate how it is divided between the front and rear. This is done by trial, using the distance of *RV* from each part as a basis and referring to Fig. 4 for relations of *V* and *L* at the disk angles existing. This method involves estimating but is believed to be useful in studying the principles involved.

A rigid frame tool differs noticeably from the jointed frame in respect to weight transfer characteristics. The weight transfer is much more controllable by the operator and the chances of mistakes on his part are greater. The heights of both *E* and *F* decide largely how much weight transfer will occur.

In either type of frame, weight transfer affects how the work of the tool is divided between front and rear. It,

together with the angle of each set of gangs, is important. The front, working in firmer soil, is nearly always loaded heavier than the rear and expected to do more work. I have asked several designers what would be the best division of work. Most of them agree that the operator wants the ground left level and that probably that is a good basis for judgment. No doubt this requirement can be met by the common styles of tandem disk by many combinations of weight distribution, joint locations, disk angles, and position of the pulling force. This problem is more complicated, however, with the offset disk.

Offset Disk Harrow. This ingenious tool has presented hard problems to both the designer and the operator. The more common disk harrow opposes the *S* and *MX* of a right-hand gang against the *S* and *MX* of a left-hand gang when both are working similar soil and have the same net weight. In contrast, the offset disk opposes a right-hand gang against a left-hand gang under the following conditions:

1 One works in looser soil than the other.

2 One nearly always has a different net weight than the other. This depends both on how the tool is made and on the amount of weight transfer which occurs while operating.

3 Changing the angle of one gang makes an opposite change in the angle of the other.

All of these factors affect the value *L* and *S* for each gang and the value of *MX* as well. The latter is more important than may seem at first thought. The *MX* of one gang opposes the *MX* of the other. Their relationship, the lateral position of the center of gravity, and a possible couple due to *PY* and the net *S* of the complete tool are all factors which decide whether penetration is uniform from side to side. Uneven penetration usually shifts the working center of a gang away from its geometric center. To sum up, a change in any one of the various factors involved causes most of the others to change, and the tool assumes a different position of equilibrium behind the tractor.

In order to study the characteristics of this tool, a considerable number of pulling tests have been made. Four lateral locations of the hitch point *F* were used and with each one careful record was made of the direction of travel, the direction and amount of pull, and the position taken by the tool. A swinging drawbar on the tractor and a piece of chain in the hitch were used to get the direction of pull. The four positions taken by the tool at one soil condition and with one vertical position of pull are shown in Fig. 8. Other tests with higher pulls, giving greater weight transfer, showed the same characteristics, but the angle taken by the tool was displaced in the direction expected.

To determine the force components on each gang in a horizontal plane, the *V* of each gang was first approximated as already explained. Fig. 4 was then consulted for an approximate value of *S*. Two conditions must be met in order to have equilibrium, namely,

1 The algebraic sum of the *S* for each gang and any side component of pull *PY* must equal 0.

2 The *RH* of each gang must have a common intersection with *PH*.

Manifestly this method involves considerable approximating. It is only as accurate as our knowledge of the characteristics of the individual disks in the soil being worked. This includes the value of *MX*, since that affects the uniformity of penetration and therefore the location of the working center of each gang. This method, however, gives a reasonable explanation for some tool positions which have previously been unexplainable. It helps in predicting how other soil conditions may affect the tool, and in explaining why 18-in disks, for example, may take a different position than 22-in disks having the same hitch point.

This difference is no doubt due to variations in *S* at large values of *V* and low angles. For example, the front section in positions No. 1 and No. 2 using a 22-in disk may with some soil conditions have a very low *S*. An 18-in disk under the same conditions would have a larger *S* in proportion to *L*. *S* and *L* of the rear gang, lightly loaded and with a large angle, would be in about the same proportion for both sizes. It is evident, therefore, that the front gang with the large disks will take a greater angle to establish equilibrium, and the angle of its rear gang will, of course, be reduced. Thus the tools will have different positions and amounts of offset.

The small change of tool position between No. 1 and No. 2 is hard to understand. It is confirmed by all other tests. Probably it is due to the sensitivity of the 22-in disks at heavy loading and low angle to the soil conditions. This is shown in Fig. 4 by the wide spread of the *S* bands at both 15 and 19 deg.

A test was also made with the hitch as in No. 2 but with 470 lb added 15 in back of the rear axle. As would be expected, this gave a larger *L* and *S* on the rear. It therefore took less angle, and the front took more angle. The change, however, was small, being less than 1 deg.

In general, a soft field and consequent deep penetration will move *H* to the right, because *L* tends to be large in relation to *S*. A very firm field has the opposite effect. This shows up very distinctly when working on firm sod with shallow penetration.

No. 2 is nearly what may be called normal offset, there

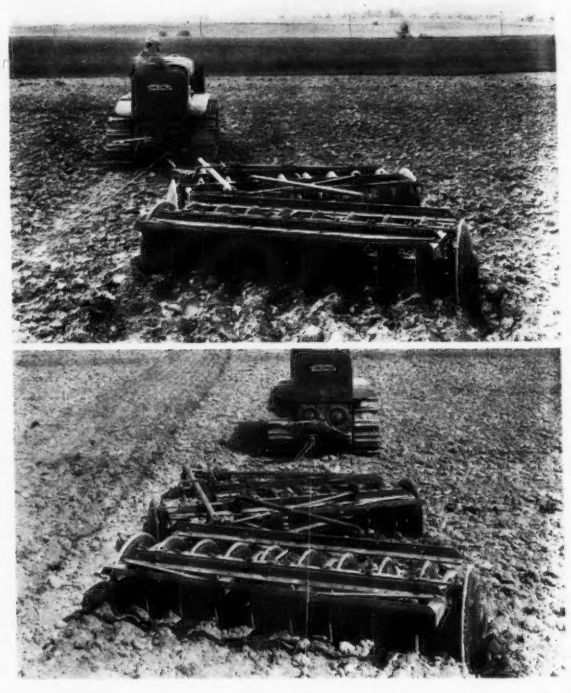


Fig. 9 Offset disk harrow in positions No. 1 and 3 of Fig. 8. The string shows the direction of travel, while the swinging drawbar and chain show the direction of pull exerted on the tool. This tool requires an angled pull unless it is offset from the tractor about halfway between the above positions

being practically no side pull on the tractor. All other positions are abnormal in that they require the tractor to exert an angled pull. Nos. 1 and 3 caused little interference with steering provided the drawbar was allowed to swing. The large side pull of No. 4, however, was enough to be troublesome. It will be noted that the draft increased from 1 to 4. That is due to greater work done by the well-loaded front gang as its angle was increased. It was very evident in 4, and to a lesser extent in 3, that penetration was not uniform. Causes for that have been mentioned. Obviously the lateral position of the center of gravity which is correct for 1 is wrong for 4. It should be moved to the left as the tool is changed from 1 to 4.

Improvement of Bearings. Probably one of the most obvious and useful ways to utilize some of the data given is in improving bearings in all types of disk harrows. Rather common faults now are (1) flexible side supports which deflect considerably under thrust loads and (2) eccentric loads.

Both of these tend to force a bearing out of correct line and thereby cause concentration of load at one end. This produces uneven wear and in one case was probably the cause of considerable breakage of bearings. Even in bumper disks, the bearings usually have some thrust, while in the rear part of a tandem harrow thrust is often the greatest load. In an offset harrow, thrust often dominates in both gangs. Both radial and thrust loads can be calculated as in Fig. 5 and Fig. 6 of reference (4), using the thrust and radial loads of a single disk as a basis and taking into account the fact that some of the weight is in the disks and axle. Possibly such calculation will show that present bearing locations could be improved. It is interesting to note that sometimes one of two bearings may be furnishing more than the total downward force needed, while the other is actually holding up the axle. For example, the disk used in the field test was composed of groups having five disks and two bearings, the bearings being in the end spaces on 27-in centers. Using the average forces given in the maximum test of Fig. 4, and allowing for the weight in the disks and axle, the average radial force on the bearing near the convex end would be 520 lb in a backward and upward direction. The radial force on the bearing near the convex end would be 340 lb in a backward and downward direction. The division of the 1025-lb thrust load is problematical as it would depend on the exact setting of the bearings and their rigidity. No doubt one bearing would carry all or most of the thrust.

Probably the best way to meet the faults mentioned is to make the bearings self-aligning. A few manufacturers already provide a considerable degree of self-alignment and that feature seems worthy of more general adoption. The tubular bearing, now in use by several California companies, is an interesting development. Considerable interest in ball or roller bearings indicates a desire to improve the plain bearings now commonly used. There would seem to be little prospect of success, however, with antifriction bearings unless their supports are very rigid or the bearings made self-aligning.

Frames and Draft Parts. On these parts there is no doubt opportunity to use strength calculations as an aid to experience and judgment. A general idea of the various forces and loads involved is useful even though their magnitudes may not be exact. Some parts will probably be most heavily loaded when a corner is being turned and knowledge of what the loads are then is scant. The frame or parts connecting the front and rear gangs of an offset disk may be one instance where calculations and shop tests of models or full-sized members might be useful. This framework must have one or more joints with vertical pins and usually needs torsional rigidity in a horizontal plane. It would be possible, of course, to get uniform penetration with a frame flexible in torsion, by having the center of gravity of each gang at the proper place. This involves practical difficulties, however, and as far as I know, no tool is built that way. The data now available can be used to determine the loading to use in shop tests so that specimens will be loaded in a manner similar to field loading.

Center of Gravity and Hitching. In all tools having no supporting wheels or surfaces, the weight and the pulling force must balance the soil reaction on the working surfaces including its moment or couple. This is a simple matter when applied to the ordinary disk harrow because in it the MX of the right-hand gangs presumably balances the MX of the left-hand gangs. This condition seldom exists in the offset harrow, hence, as previously mentioned, the lateral location of the center of gravity is vital if uniform penetration is to be secured.

Wheatland disks and disk plows differ from the above tools by having wheels which carry part of the weight and furnish the side reaction to balance $S \pm PY$. The hitching is then similar to that of a three-wheel moldboard plow, the principal difference being that in difficult penetration the upward portion of the soil reaction is greater, and it is more often important that nearly all weight be available for overcoming a large V and any upward PZ. Many combinations of pulling force and center of gravity locations are possible. They will differ, however, as to how they distribute the side reaction between front and rear wheels, and as to how any weight not used in balancing V and PZ is divided among the three wheels.

Fig. 10 helps explain the principles involved. A large upward V is shown so that the wheels will be carrying little weight. For accuracy, the rolling resistance of wheels should be added vectorially to L. It is a small item, however, when the disks are carrying most of the weight, and for simplification is considered as included with L in Fig. 10.

If H is placed differently on RH by shifting the pulling force sideways, it is evident that the side force will be divided differently between the furrow wheels. If PV is moved vertically, the weight carried by wheels will be redivided, also S will be higher or lower. The latter will change the value of the couple caused by $S \pm PY$ and the side reaction of the wheels, since their reaction is practically where they touch the ground. The original loading on front and rear wheels can be restored by shifting W ahead or back. Within reasonable limits it appears that a number of combinations of location of weight and pulling force may be satisfactory, also that the pull may have various Y and Z components. The tests reported here probably do not cover as difficult penetration as may occur, but they serve to show the principles involved in making most of the weight available for penetration. All weight carried by wheels is, of course, not being used for penetration. Perhaps an ideal to seek would be to have the loading of the land wheel approach zero first. The furrow wheels need some vertical load to prevent their climbing the sloping furrow wall under the influence of the side force on them. The location of W can be worked out for any particular case by putting proper values of forces and distances in Fig. 10, then using moment equations and solving for the location of W. Such calculations, supplemented by field trials, should be useful in working out the best practical solution of the interrelationship of soil reaction, pull, and weight location.

AUTHOR'S ACKNOWLEDGMENT: Credit is due Prof. K. J. DeJuhasz for valuable suggestions on apparatus and methods.

Flow of Heat Through Roofs

By Aldert Molenaar and R. L. Perry

RAPID INCREASE of interest in summer comfort cooling has been forcing more and more attention to the problem of flow of heat through roofs. Until recently, with a few notable exceptions[1,2], the design procedure has been to base heat transmission on steady state coefficients, with a rather arbitrary addition to the outside temperature for roofs and walls exposed to solar radiation. As pointed out by Woods and Raber[3], more than 40 per cent of the heat entering a typical uninsulated five-room, one-story cottage comes through the roof. It seemed appropriate therefore that additional attention be given to the actual performance of different roof types.

Although the thermal properties of building materials are fairly well known for steady state heat flow, it is as yet impossible to predict exactly the performance of a given roof under actual conditions because of the complex relationship between the several factors under fluctuating heat rates and temperatures. The temperature rise under the roof is influenced by the solar energy, the cloudiness, the air temperature and movement, the roof angle, the reflectivity of the roof surface, the conductivity, thickness and heat capacity of the roof structure and its insulation, and the thermal characteristics of the enclosed space.

Before sunrise the roof surface temperature is usually below the air temperature because of radiation to the sky at night, but the roof structure is warmer than the surface, and is losing heat to the surface. When solar energy strikes the roof some is absorbed, and the temperature of the surface rises. As the surface temperature rises, heat is conducted into the roof structure, and some is lost by convection to the now colder air. On a south slope the impinging radiation is greatest at noon, but the surface temperature continues to rise for some time after noon because the air temperature is still rising and tends to limit the convection loss. After about 2 p.m., the surface temperature starts to fall, but heat is still flowing into the roof structure because it is not yet as warm as the surface. As the sun approaches the western horizon, the roof surface drops more rapidly, and heat flows out from the adjacent layers, although the temperature wave may still be flowing in further in the structure. Heat continues to flow out during the night, and the next day the cycle is repeated.

For the purpose of comparing the heat absorption and transmission of a number of roof types and insulation applications, four roof heat-flow test boxes were set up at Davis, California, in the summers of 1936 and 1937. The boxes (Fig. 1) consisted of double walls and floors of one inch sheathing spaced 4 in apart by studs. The stud space was filled with redwood bark fiber, and the inside and outside of the boxes were covered with type B aluminum foil paper. Two hundred pounds of bricks were placed on a sheet of insulating board spaced ½ in above the bottom of the box, to serve as heat capacity. The boxes were faced due south and tilted at an angle of 27 deg above horizontal. Recording thermometer bulbs were placed between the bricks in the lower part of each box, while one additional bulb was used to record air temperature. The several roof test sections, 27x60 in, were then installed on the boxes with a gasket between box front and sheathing to minimize air exchange.

In addition to the recorder records, several 24-hr runs were made to measure roof surface, sheathing surface, lower insulation surface, box, air, and recorder bulb check temperatures with thermocouples. A typical curve is shown in Fig. 2.

Since no recording solar energy meter was available, a weathered shingle roof on solid sheathing was used as a check roof on the first box, for all tests. The air temperatures and the performance of the check roof are given in Table 1. It was necessary to select from each run a period for which the last day's temperatures were about the same

Presented before the Farm Structures Division at the annual meeting of the American Society of Agricultural Engineers, at Asilomar, Pacific Grove, Calif., June 30, 1938, and subsequently revised for publication in AGRICULTURAL ENGINEERING. Mr. Molenaar (Mem. A.S.A.E.) was graduate student in agricultural engineering at the University of California when he made this study, and is now assistant extension agricultural engineer, University of Nebraska. Mr. Perry (Mem. A.S.A.E.) is assistant professor of agricultural engineering, University of California.

[1]A.S.H.V.E. Guide, 16th Edition, pp. 150-157, 1938.

[2]Houghten, F. C., Carl Gutberlet, and A. A. Rosenberg. "The Effect of Solar Radiation on the Heat Transmission Through Walls." Am. Soc. Testing Materials Bul. 96:39-46 January 1939.

[3]Woods, B. M., and B. F. Raber. "Air Conditioning for California Homes," University of California Experiment Station Bulletin No. 589. 1935.

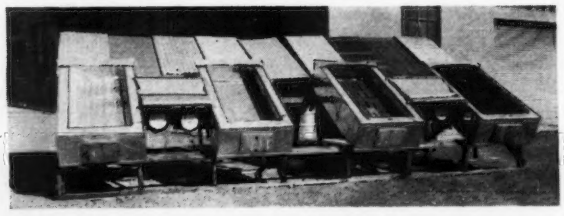


FIG. 1 ROOF HEAT-FLOW TEST BOXES. BOX 1, AT THE LEFT, IS EMPTY AND THE ROOF IS IN PLACE ON BOX 4, AT THE RIGHT

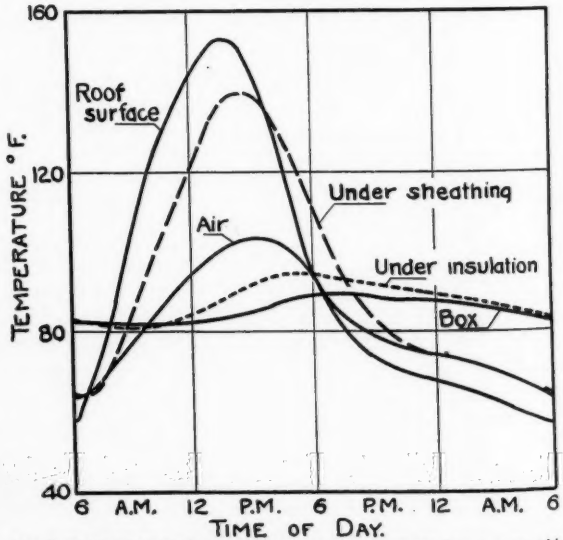


FIG. 2 ROOF TEST TEMPERATURES FOR RUN 9, ROOF 21C, WITH 3½ IN OF ROCK WOOL INSULATION

as the first, in order to minimize the effect of overall temperature changes in the box.

The range of temperature of the recording thermometer (maximum minus minimum) is a rough measure of the heat received during the day. There are two corrections to be applied. The first is based upon the fact that, even if the roof were a perfect insulator, the box is not, and it would show a fluctuation in inside temperature which would depend upon its heat capacity and conductance. In order to evaluate this, a box was set up in a controllable temperature room, with a section of insulation 15½ in thick in place of the usual roof. The room temperature was manipulated to duplicate a typical daily variation for several days. With an air range of 40.1 F (degrees Fahrenheit), the box range was 3.7 F, or 9.3 per cent. If the roof were a perfect insulator (15½ in of bark fiber is almost infinitely thick for a 24-hr cycle), the box range would be expected to be 9.3 per cent of the air range for similar wave forms. If the roof were such a poor insulator that the box range equalled the air range, there would be no correction to the observed box range for interchange through the box walls. Thus the correction for interchange through the walls is proportional to the air range, and to the box range itself. For a range ratio of 9.3 per cent, it can be shown that the value of the box range corrected for interchange is $1/(1-0.093) \times$ observed box range $- 0.093/(1-0.093) \times$ observed air range, or $1.1 \times$ observed box range $- 0.1 \times$ air range.

The second correction is necessary to take care of the fact that the average temperature of the box is above the average air temperature. This indicates that, in addition to the heat absorbed by the bricks, there is over 24 hr, a loss of heat proportional to the difference in the average temperatures. In order to evaluate this, a box was set up in a constant temperature room, with a thin hot water tank for supplying an amount of energy which could be measured by the circulation rate and temperature change. In one test the heavily insulated cover mentioned above was used; in the other, one box was inverted over the first. The average value of heat loss rate was 50 Btu per day per degree difference in temperature between the tank and the room. Since the heat capacity of the bricks is 200×0.2, or 40 Btu per degree temperature change (0.2 being the specific heat), one degree difference between box and air averages represents as much heat as 50/40, or 1.25 F change in temperature of the box.

The corrected range is then

$1.1 \times$ observed box range $- 0.1 \times$ air range $+ 1.25 \times$ (box-air) average.

In order to compare roofs tested on different runs, when the air temperatures and check roof performance varied as shown in Table 1, the corrected relative range, that is, the corrected range divided by the corrected range for the check box, was computed for each roof test. The results of the tests are shown in Table 2, in which the roofs are arranged in order of their relative ranges to facilitate comparison rather than in groups of the same run. Errors

TABLE 1. ROOF TEST CONDITIONS AND CHECK ROOF RESULTS

Run No.	Air temperature, deg F				Check roof (No. 9) temperatures, deg F					
	Min	Max	Ave	Range	Min	Max	Ave	Roof-air average	Range	Corrected range
1	61.3	97.7	79.5	36.4	73.1	94.1	83.6	4.1	21.1	24.7
2	62.9	103.9	83.4	41.0	78.4	100.2	89.3	5.9	21.7	27.1
3	62.3	99.3	80.8	37.0	77.2	96.7	87.0	6.2	19.5	25.5
4	53.4	92.1	72.7	38.7	67.7	89.0	78.4	5.7	21.4	26.8
5	63.0	102.0	82.5	39.0	77.7	97.6	87.6	5.1	19.9	24.4
6	58.6	98.2	78.4	39.6	72.9	95.2	84.0	5.6	22.3	27.6
7	62.2	100.3	81.2	38.1	77.2	99.2	88.2	7.0	22.1	29.2
8	56.6	96.0	76.3	39.4	71.5	94.1	82.7	6.4	22.6	28.9
9	52.8	92.6	72.7	39.8	69.6	90.6	80.1	7.4	21.0	28.6
10	56.4	92.4	74.4	36.0	68.7	89.1	78.9	4.5	20.4	24.5
11	51.8	88.2	70.0	36.4	63.5	85.5	74.5	4.5	21.9	26.1
Wt. ave.	58.4	96.3	77.3	37.9	72.5	93.7	83.1	5.8	21.2	28.8

TABLE 2. TEST DATA AND SUMMARY

No.	Roof No.	Description	Computed* conductance	Run No.	Range, deg F	Box-air, average deg F	Relative range**, corrected
1	21c	3½-in rock wool fill	.07	9	7.8	2.1	0.25
2	21b	3½-in redwood fiber fill	.07	8	7.5	3.1	0.28
3	23a	Aluminum foil paper under rafters	.16	7	11.2	0.3	0.30
4	21d	3½-in glass wool fill	.07	10	8.4	2.0	0.32
5	23c	Aluminum foil paper between rafters	.13	9	11.2	1.3	0.35
6	22d	1¾-in glass wool fill	.11	10	10.6	2.6	0.46
7	23b	Aluminum foil paper against sheathing	.24	8	16.4	1.3	0.51
8	22c	1-in celotex under rafters	.16	9	13.5	3.4	0.54
9	22a	½-in celotex under rafters	.20	7	14.2	4.6	0.60
10	23d	Kraft paper between rafters	.20	10	14.7	1.8	0.61
11	21a	Kraft paper under rafters	.27	7	16.3	3.9	0.65
12	22b	½-in celotex against sheathing	.24	8	17.3	4.6	0.72
13	11ap	Aluminum painted wood shingles	.34	3	16.2	4.1	0.75
14	7a	Galvanized iron on sheathing, aluminum paint	.40	3	18.8	2.4	0.78
15	21	New wood shingle, check run	.35	11	21.0	2.0	0.84
16	23	" " " " "	.35	6	21.3	3.1	0.85
17	22	" " " " "	.35	11	21.8	1.8	0.87
18	10wp	White painted wood shingles, one coat	.35	3	18.8	4.4	0.88
19	22	New wood shingle, check run	.35	6	22.5	3.6	0.92
20	23	" " " " "	.35	11	22.8	2.0	0.92
21	21	" " " " "	.35	6	22.3	4.3	0.94
22	10w	Old white painted wood shingles	.35	2	22.1	4.9	0.97
23	9	Old wood shingles, standard check	.35	all	21.2	5.7	1.00
24	11a	Old aluminum painted wood shingle	.35	2	22.4	6.3	1.05
25	7	Galvanized iron on sheathing	.41	2	27.5	5.9	1.24
26	1a	Galvanized iron on strips, aluminum paint	.70	5	29.8	1.9	1.28
27	1b	Galvanized iron on sheathing	.41	1	25.8	5.7	1.29
28	6a	Green slate asphalt slabs	.40	4	29.7	7.0	1.40
29	6a	" " " "	.40	5	27.7	6.9	1.44
30	3	Old white mineral roll roofing	.45	4	33.0	5.7	1.47
31	8	Red slate composition shingles	.45	1	27.8	7.8	1.48
32	31	Copper on felt	.41	5	28.4	11.1	1.69
33	2	Galvanized iron on strips	.71	1	35.5	5.5	1.71
34	4	Green slate roll roofing	.45	4	36.7	8.8	1.77

*Computed by A.S.H.V.E. recommended practice, Btu/ft²/hr/deg F

**Relative range is corrected range ÷ range of check box for same run. Corrected range is $1.1 \times$ observed range $- 0.1 \times$ air range $+ 1.25$ (box-air) average, probably accurate to within 0.05.

in the relative ranges result from an overall gain or loss in heat during the test period, and from differences in the temperature wave form. They are believed not to exceed 0.05. In addition to the range and the box-air average taken directly from the test data, the unit conductance for the roof and its insulation computed according to the recommended procedure of the A.S.H.V.E. is given.

As mentioned above, the heat capacity of the bricks was 40 Btu per deg F. The corrected range of the check box was 26.8 F, indicating a heat absorption of 1072 Btu. The net roof area was 11.7 sq ft; thus the heat absorbed was 92 Btu per sq ft. The relative range of the check box being 1.00, of course, it can be seen that the heat absorbed per square foot for each test is 92 times the relative range, or roughly 100 times the relative range. Only a small fraction of the 2000 Btu per day incident energy per square foot reaches the interior of the box. Part is reflected, especially at low angles, part that is received is lost by convection, and some is absorbed by the roof structure and its insulation.

Wood shingles on solid sheathing gave the best performance of any of the uninsulated roofs. Although galvanized iron on strips made a very hot roof, galvanized iron on sheathing was only about 25 per cent hotter than wood shingles on sheathing, and was considerably cooler than roll roofing or composition shingles. The heavy green slate-surfaced asphalt slabs, which are claimed to have some insulation value because of lengthwise air cells, proved only a little better than composition shingles.

The effect of bright aluminum paint was quite marked, making the galvanized iron on strips as cool as unpainted galvanized iron on sheathing, and making that on sheathing as good as aluminum-painted wood shingles. On shingles the aluminum paint was as good as a ½-in sheet of board form insulation placed against the sheathing. The old aluminum and white paints were badly weathered, one-half to two-thirds of the surface being bare. The new white paint was only one coat.

The several check runs on new wood shingles were made before and after the insulation tests, in order to disclose any variation in the three shingle roofs which were used. In the description of the insulation, the designation "against the sheathing" is self-explanatory. "Under the rafters" refers to insulation nailed on the under side of the rafters, making a 3½-in air space. In "between the rafters" the insulation was installed in the rafter space with narrow wood strips, and a sheet of ¼-in three-ply panel was nailed against the rafters, thus making two 1½-in air spaces. As would be expected, the insulating board and the kraft paper intended to give air space insulation both gave better results between rafters than under rafters. The reason why the aluminum foil paper did not do so is not apparent.

In general, the performance of the insulated roofs was about what would be expected from the computed conductances. The heat capacity of the insulation was less important than had been anticipated. This is because the insulation offers little additional heat capacity. The shingles and sheathing weighed about 50 lb, while the 3½-in thickness of redwood bark fiber weighed 18 lb, and the 3½-in thickness of glass wool, 5 lb.

The kraft paper was used in order to show how much of the insulating effect of the aluminum foil paper is due to the air space. Apparently about half of its value is due to the air space and radiation shield effect and half to the high reflectivity. The insulations which included large air spaces proved better than would have been predicted, probably because the air space is more effective in preventing heat inflow in the daytime than in hindering outflow at night.

The effect of insulation thickness can be roughly stated as follows: ½ in stops one-fourth to one-third of the heat which would flow through a wood shingle on sheathing roof; 1 in, one-third to one-half; 2 in (1¾), one-half to two-thirds; 4 in (3½), two-thirds to three-fourths.

Although it is not customary to place insulation in the roof structure itself, except in the case of occupied gables, the heat capacity of the box load of bricks is such that the results can be reasonably well adapted to the case of second story rooms with insulation above. The temperature ranges in each case will be about comparable, except for the effect of forced ventilation. With adequate ventilation, the insulation is more effective than these test data show, because of the forced dissipation of heat at night.

METAL AS A FARM BUILDING MATERIAL

Metals of varying kinds, combinations, and properties for different structural members, and in several degrees of prefabrication, are becoming increasingly available as farm building materials. This adds to the agricultural engineering problem, responsibility, and opportunity of combining materials in structural and functional design to meet use requirements in ways that contribute to lower farm operating costs per unit of production

An Approach to the Study of Flood Peak Formation

By F. E. Hardisty and H. B. Ingersoll

UNTIL THE past year the government agencies most actively interested in floods and flood problems have been the Corps of Engineers of the War Department, the Geological Survey of the U. S. Department of the Interior, and the Weather Bureau of the U. S. Department of Agriculture. Of these, the Corps of Engineers is engaged in the study of flood phenomena and in the application of large-scale remedial projects on large streams which cause exceptional flood damage to life and property at particular locations; the Geological Survey, in its presentation of stream runoff data, is especially interested in stage and discharge maxima which occur during floods; and the Weather Bureau is concerned with flood crest prediction.

Recently, however, the Department of Agriculture has been charged with making flood control surveys on certain selected flood source watersheds to determine the flood control value of agricultural conservation practices. These surveys, which enjoy the complete cooperation of those agencies interested in other phases of the flood problem, are intended to supplement large-scale national flood control works on main streams by fostering soil and water conservation on the agricultural lands above them.

As a result of this rational cooperative approach to the study of flood problems, the engineers' conception of major floods is undergoing a change. From the upstream engineering or "little waters" standpoint the peak flows on main floodways are beginning to be considered as the sum of discharges from the many small tributaries contributing to them. Such a transition is to be expected at this time because conservation programs on agricultural land are just beginning to take their place as an integral part of a coordinated national effort toward flood control.

In practice many difficulties immediately develop in attempting to study the cumulative effect on floods of discharge from innumerable tributaries. Particularly difficult is the evaluation of conservation practices on agricultural land as flood-reducing agencies on the smaller streams, and the summation of such reductions on the main rivers. It is found that by the time river systems have developed into floodways sizable enough to be causing serious annual damages to population centers they include significant flood contributing tributaries numbering in the hundreds. These small units range in drainage area from 3 to 60 sq mi and may average not more than 25 sq mi. When these tributaries are considered as flood contributors at any given danger point in the main river system below, the study of them becomes involved. The number of units concerned and the complexity of their assembly makes use of hydrographs and the usual flood routing procedure difficult, particularly when adequate stream and precipitation gage data are lacking.

To simplify the contemplation of such a system of tributaries, a classification of them is helpful. For any major flood-producing drainage the first step is to segregate the main streams serving as delivery arteries for the system and classify them as first-order streams. Then, by examination of the physical features of the remaining smaller tributaries, such as their gradient, drainage area, channel length, shape, etc., they can be grouped into lower orders by their similarities in hydraulic characteristics. The number of classifications or orders desirable, of course, depends on the variety of conditions occurring in the system studied, but it is rarely necessary to make groupings below the fourth order. Since the classification is made on the basis of flood discharge characteristics, the tributary gradient should be the principal criterion for segregation. In this manner flood discharge from second order streams forms a peak more slowly than lower orders. In borderline cases, where it is doubtful by the gradient criterion alone into which order a given tributary belongs, an examination of its features affecting time of concentration, such as length, relation of length to area, shape, etc., will place it at once in its proper category. After such classification it is found that the areas and lengths of tributaries in each classification agree remarkably well, considering they were separated mainly by gradients.

It is next necessary to consider the position of each tributary with respect to the watershed itself, so as to synchronize its flood discharge in terms of the natural structure of the entire system. The tributaries of each order are tabulated and their discharge distance to the problem point measured. Any tributary may deliver its discharge through any combination of various other streams to the first-order artery and thence to the problem point. Distances can be tabulated for each tributary to this point, or, by calculating typical flood velocities for second, third, and fourth-order streams and average velocities for selected reaches of first-order tributaries, this distance in miles, under conditions of stabilized channel storage, may be reduced to time. This information can then be presented for any problem point by plotting either square miles of drainage area or peak discharge against miles or time. The result is a graphical representation of flood peak formation in a single or a combination of first-order streams as caused by the synchronized contributions from each minor tributary discharging in its definite time and place.

For the purpose of dealing in terms of peak discharges, one of several alternatives may be used. For example, where stream gage records exist on small streams representative of the orders of tributary classification, a typical unit graph of each order may be reconstructed. Similarly the distribution graph can be conventionalized for each order tributary. These data, summed up for the system, show the flood assembly graph for that system. An alternative is to solve, in any given system, for the proportionate rate of discharge from each classification which, when assembled as above, coincides with the maximum rate of discharge recorded for the system. In either case, the assembly graph obtained should check recorded flood hydrographs for the system in shape and in crest sequence. For any such system it is found that substantially the same small tributaries form the flood peaks, except in the unlikely case of very prolonged or spotty flood discharges.

Approved for first publication in AGRICULTURAL ENGINEERING by the Soil Conservation Service, U. S. Department of Agriculture. Mr. Hardisty (Mem. A.S.A.E.) is agricultural engineer and Mr. Ingersoll is assistant civil engineer, Flood Control Survey, Soil Conservation Service.

To evaluate beneficial effects at any particular point resulting from a conservation program, the same method is used. The estimated reduction in peak runoff for each land use is computed by any one of several accepted methods of summation on selected representative tributaries in each classification. With this reduced runoff figure for each tributary group the synchronized total is reassembled above the problem point, and the new peak formation is a measure of the effectiveness of the flood control program.

Although the possibilities of this method of flood analysis have yet to be fully explored, its practical uses at this time appear to be as follows:

1 To rationalize and clarify the synchronization phenomenon at any problem point on any stream.

2 To guide control reservoir location by mathematically considering synchronization as well as maximum flood discharges.

3 To improve flood control reservoir operation by accurately anticipating crest sequences.

4 To facilitate more accurate prediction of flood crest times at danger points.

5 To determine, in conservation operations, which tributaries contribute most to flood peaks at problem points so that remedial efforts can be concentrated on them.

6 To choose, by study of the synchronization charts, where retardation or acceleration of tributary discharges is applicable in order to affect beneficially flood peaks at the problem point.

7 To reduce study of flood peak formation to a comparatively simple tabular operation.

8 To facilitate quick analysis of expected cresting from flood producing rains of any pattern.

The exposition of tributary classification and synchronization presented here is in the nature of a preliminary report on the methods developed and currently in use. Within the year representatives of two interested departments of the federal government will cooperate with the authors in presenting a study of a flood producing watershed by these methods, completely documented with supporting tabular and graphical data.

Discussion by F. M. Bell

THE procedure outlined by Mr. Hardisty and Mr. Ingersoll, by which a better understanding of flood peak formations may be obtained, is extremely interesting. Even if all the aims of the authors are not realized, there is no doubt but that much can be learned about flood peak formations by a thorough study of the hydraulic characteristics of tributaries in a flood producing system.

As in all methods of dealing with flood flows, this method requires a certain amount of basic data on rainfall and runoff for the various orders of tributary classification. The more data of this kind there is available the greater will be the success in applying this or any other method of determining peak discharge. In addition to the necessary hydraulic data, in order to properly classify tributaries it appears that the first requirement will be an accurate topographic map of the drainage areas of the watershed. This requirement can be fulfilled for some watersheds, but the lack of proper maps for a large part of the country will probably prevent the use of any computations which require determination of the physical features of all tributaries.

Further results of the application of the proposed method will be awaited with interest.

Mr. Bell is district engineer, U. S. Geological Survey, at Atlanta, Georgia.

Discussion by Leon Lassen

DEVELOPMENT of the process of integrating the runoff from the smaller drainage units to reproduce the runoff hydrograph at a point on a larger stream has come at a time when the need of such information was acutely felt by those engaged in flood control studies. To the men engaged in upstream engineering, the integration process will enable quick and accurate decisions as to which of the smaller units should be improved so as to destroy the synchronism of their flows. It has been apparent to the engineering profession for a long time that flood control structures improperly located may change the timing of peak flows so as to increase flood crests at selected locations. In order to avoid the misplacement of a flood structure, laborious methods of flood routing have been employed. The integration process, once developed for a specific area, can be used to forecast the effect of a proposed improvement with but a small percentage of the labor involved when flood routing methods are used.

The shape of a flood hydrograph at any point on a main stream is a reflection, to a large extent, of the physical characteristics of the watershed and the distribution of the flood producing rainfall. If a uniform rain of duration less than the period of concentration is assumed, the higher rates of flow are the result of the synchronism of the flow from certain of the unit areas above. The integration process enables the isolation and identification of these areas. Once identified, it then becomes a matter of engineering procedure to delay or advance correctively the crests of a sufficient number of these critical streams so as to reduce the peak flow at the point under consideration.

From this brief analysis of the method it becomes immediately apparent that its usefulness to the engineer is unlimited. If consideration is given to a reduction of runoff on several of the smaller areas by means of changes in surface cover, the reduced flows will be integrated with the unchanged flows from the other streams and the resulting peak at the downstream point will show somewhat lesser magnitude. Should some flow-retarding devices be desirable on several of the areas which synchronize to produce a peak flow, the peak flows from these streams will be delayed. In some cases it may be desirable to hasten the arrival of certain of the peak flows from the smaller areas in order to destroy the synchronism which accounts for the magnitude of the peak on the main stream. This can be accomplished in a great many cases by channel improvement.

The integration process can be made to indicate which of the possible improvements is the most desirable in any small drainage, and to evaluate the effect of the chosen improvement. Further, in a great many cases the only practicable way to destroy adverse synchronism is to store the flow from several of the areas (if topographic conditions are favorable for storage) for such time as may be considered desirable to correct the formation of flood crests on the main stream. The integration process will indicate the effect of the removal of the volume of storage and the most desirable time for its release.

Since the integration process identifies the areas whose streams combine to produce the peak discharge at some point on the main stream, and since the method also indicates the time distance of these areas from the point, the process can be developed for flood prediction purposes. This angle should be given further detailed study by the authors. If a sufficient number *(Continued on page 230)*

Mr. Lassen is associate engineer, U. S. Engineer Office, Mobile, Alabama.

Silo Pressure and Temperatures with Corn and Grass Silage

By J. R. McCalmont and H. E. Besley

A STUDY of the pressures exerted by corn silage in round silos was started by the Bureau of Agricultural Engineering, U. S. Department of Agriculture, in the fall of 1936. This study came to the attention of W. C. Krueger, extension agricultural engineer at the New Jersey College of Agriculture, who knew of several failures of silos used for hay and molasses silage. Correspondence between Mr. Krueger and the Bureau regarding pressures in silos filled with such material resulted in a cooperative study on grass silage pressures at the New Jersey North Branch Experiment Station.

Experimental Setup. Since the system used to measure the pressures exerted by both corn and grass silage was the same, the pressure panel setup used for corn silage at Beltsville in a 14x44-ft monolithic concrete will be described, and the results of 3 years' tests on corn silage and 2 years on grass silage will be given.

The setup for measuring pressures was the same as used by the Bureau of Agricultural Engineering to determine the pressures exerted by ear corn in cribs, reported in AGRICULTURAL ENGINEERING for November 1934. In the present study the pressure panels replaced the regular silo doors. Special door jambs of 2-in channel sections were introduced to support the panels on $\frac{5}{8}$-in round steel rods. The panels were made up like regular silo doors except that $\frac{1}{2}$-in clearance was allowed around each door. Two lengths of 3-in T-section were bolted vertically to each door, 12 in outside to outside faces, each having $\frac{3}{4}$-in holes drilled 2 in from the door and $6\frac{1}{8}$ in on either side of the horizontal center line of the door. Fig. 1 shows sections through the doors and the door opening and a view of the door. The $\frac{5}{8}$-in rods passed through the $\frac{3}{4}$-in holes in the T-sections bolted to the doors and rested in $\frac{3}{4}$-in holes drilled in the 2-in channel section door jamb. The doors were covered inside with a strip of copper-armored fiber paper creased along the edges to allow freedom of movement in the panels.

The rods were calibrated on a standard testing machine for twice the expected loads, using points of loading and support identical to those in the actual setup. The deflection over a 10-in gage length at the center of the rod was taken with the deflectometer shown in Fig. 1, which was equipped with both horizontal and vertical level glasses and with an Ames dial graduated to read deflections to the nearest 0.0001 in. The rods were heat-treated to have a yield point of 125,000 lb per sq in and were of uniform quality. The average calibration constant was 1.3 lb per 0.0001-in deflection. Since the variation from this constant was no greater than the limit of accuracy of the testing machine, this average figure was used in computing the pressures exerted on the panels in the silo. Since the deflectometer was equipped with both vertical and horizontal level glasses, it was possible to read the vertical and horizontal components of the forces acting on each $\frac{5}{8}$-in rod supporting the panels. The horizontal component was the lateral pressure exerted against that portion of a panel it supported and the vertical component was a measure of the weight of silage supported due to the friction between the silage and the panel.

Corn Silage Pressures. Pressure readings at Beltsville of both the horizontal and vertical forces on each panel were taken for each 2 ft of silage placed in the silo. These readings could be repeated with a variation of less than 0.0003 in, which represents 3.9 lb. Since the loads measured varied from 40 to 1,500 lb on one rod, the experimental error introduced would vary from 10 to 0.2 per cent, and the average error when the depth of silage was 12 ft or more was 1 per cent or less. There were variations in the panel pressures at different heights which were probably due to changes in the rate of filling, differences in the moisture content of the corn, and the amount of compaction in the silage. The average maximum lateral pressure for three tests before the silo was opened was 325 lb per sq ft, which occurred on the bottom panel two days after filling, and the average maximum vertical pressure was 212 lb per sq ft. After the maximum was reached, the pressures showed a tendency to decrease until the silo was opened.

After 10 ft of silage had been fed out, the pressure on the two top panels changed direction and pushed up on the panels. The amount of this reversed load increased as the top level of the silage approached the bottom of the door opening and is shown graphically by the vertical pressure curve in Fig. 2. This curve also shows how the lateral pressure increased as the head decreased. This increase was so large as to make the maximum lateral pressure approximately 350 lb per sq ft on the bottom panel, which is 25 lb greater than the maximum pressure when the full silo had settled 2 days. This being quite unusual and unexpected, we offer the following explanation: Sil-

Presented before the North Atlantic Section of the American Society of Agricultural Engineers at Boston, September 1938 and before the Farm Structures Division at the fall meeting of the Society at Chicago, Ill., November 30, 1938. Mr. McCalmont (Mem. A.S.A.E.) is assistant engineer, Bureau of Agricultural Engineering, U. S. Department of Agriculture, and Mr. Besley (Mem. A.S.A.E.) is assistant professor of agricultural engineering, New Jersey State College of Agriculture, Rutgers University.

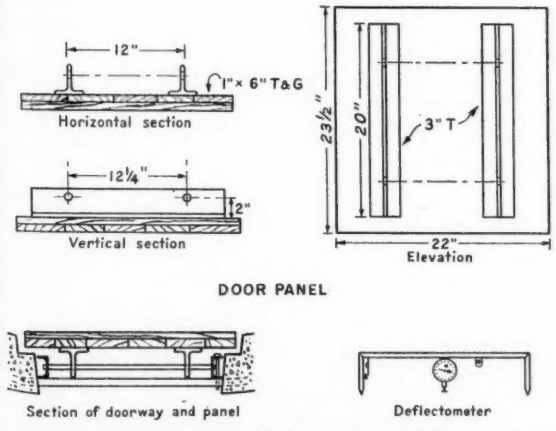
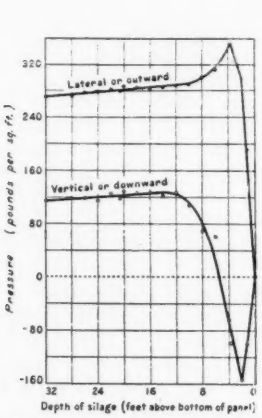
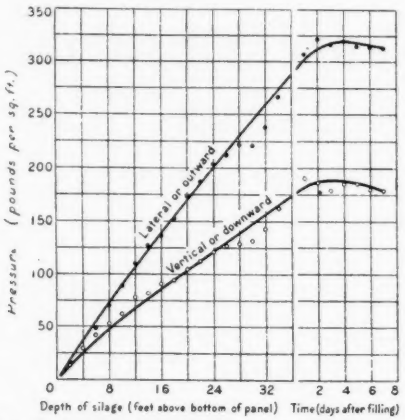


FIG. 1 EQUIPMENT USED IN PRESSURE STUDY




Lateral or outward
Vertical or downward
Pressure (pounds per sq. ft.)
Depth of silage (feet above bottom of panel)
Time (days after filling)

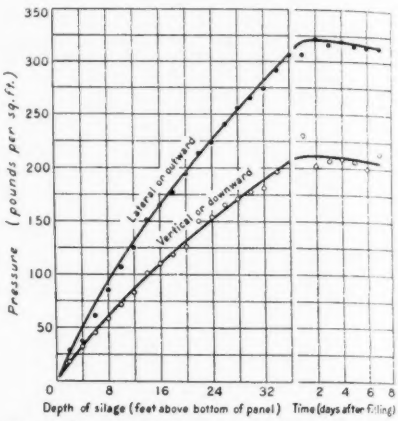

Lateral or outward
Vertical or downward
Pressure (pounds per sq. ft.)
Depth of silage (feet above bottom of panel)
Time (days after filling)

FIG. 2 (LEFT) LATERAL AND VERTICAL PRESSURE ON PANEL NO. 1, THE BOTTOM PANEL IN A 14-FT DIAMETER SILO, AS THE SILAGE WAS FED OUT OF THE SILO. FIG. 3 (CENTER) AVERAGE PRESSURES ON ALL PANELS WITH THE SAME DEPTH OF SILAGE ABOVE THEM IN THREE TESTS OF A 14x44-FT SILO FILLED WITH CORN SILAGE. FIG. 4 (RIGHT) AVERAGE OF THREE TESTS OF PRESSURE ON PANEL NO. 1, THE BOTTOM PANEL, AS THE DEPTH OF SILAGE INCREASED IN A 14X44-FT SILO FILLED WITH CORN SILAGE

age, like other coarse materials, arches between the walls of the silo, giving a lateral pressure and a vertical pressure that is a product of the lateral pressure and the coefficient of friction between silage and the silo wall. As the silage settles these arches gradually flatten out and the maximum pressure occurs when the arches become flat, from one to three days after filling ceases. As settling continues the center becomes lower than the edges, forming an inverted arch which allows the lateral pressure to decrease a small amount. In addition to this, the silage settles along the walls. Consider this action as if the ends of the arches were sliding down the walls of the silo, always remembering, however, that the center goes down more than the outside, the entire mass becoming very compact. When the silo is opened and a certain amount has been fed out, the silage again expands. This expansion is greater in the center and the compacted arches again tend to flatten out, becoming flat, thus giving the maximum pressure when there is approximately 4 ft of silage above the bottom of the door opening, or 10 ft in the silo. Had the silo not had a pit, this maximum pressure might have occurred on the third or fourth panel rather than the bottom panel. On the other hand, it might still have occurred in the bottom or second panel and have been greater than was shown in this test.

When the pressures on each panel with the same depth of corn above were averaged and a composite average was made for the three experiments, the outward pressure on the walls per square foot for each foot of depth was found to be approximately 8 lb laterally and 5 lb vertically when based on the total height of the silo. The results of these averages were plotted in pounds per square foot and gave the curves shown in Fig. 3. These curves are very similar to curves in Fig. 4 plotted the same way from the pressures read on panel No. 1, the bottom panel, as the head or depth of silage increased. In 1937 and 1938 the silo contained approximately 150 tons of silage, 25 tons more than in 1936 the greater weight being due to a shorter length of cut. Fig. 5 shows the approximate amount of silage placed in the silo and its density at various depths before and after settling.

In September of this year the 18x43-ft concrete stave silo at the New Jersey North Branch Experiment Station, that was used to start the grass silage pressure investigations in 1937, as discussed later in this paper, was filled with 264 tons of 74 per cent moisture corn silage. The lateral and vertical pressures obtained in this test are shown graphically in Fig. 6 and the density at various depths are included with Fig. 5.

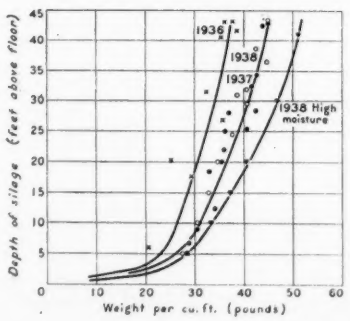
The maximum pressures for this 18-ft diameter silo are about 50 per cent higher than those measured in the 14-ft diameter silo. This increase in pressure perhaps can be attributed to the greater diameter or the increase in the ratio of diameter to height or the greater moisture content. The increase in pressures that can be charged to either factor will have to be ascertained by further tests. These results indicate, however, that we do not yet know all the factors affecting silage pressures, and that 8 lb per sq ft per foot of depth, or even 11 lb, is not a safe figure for corn silage under all circumstances. On the basis of these tests we cannot recommend any reduction in the amount of reinforcing used in silos for corn silage.

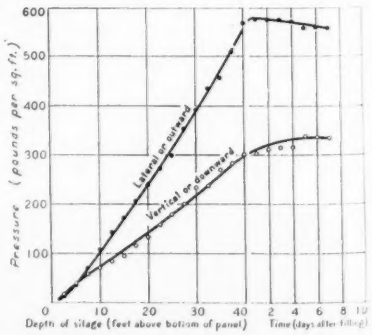
Grass Silage Pressures. The work on grass or leguminous silage pressures started in July 1937, when an 18x43-ft

FIG. 5 (LEFT) DENSITY OF CORN SILAGE DURING FILLING

1936—14x44-ft silo, capacity 125 tons, 71 per cent moisture, ½-in cut
1937—14x44-ft silo, capacity 149 tons, 68.5 per cent moisture, ¼-in cut
1938—14x44-ft silo, capacity 151 tons, 70.2 per cent moisture, ¼-in cut
1938—18x43-ft silo, capacity 264 tons, 74 per cent moisture, ¼-in cut

FIG. 6 (RIGHT) AVERAGE OF ALL PANELS WITH THE SAME DEPTH OF SILAGE ABOVE THEM WHILE FILLING AN 18x43-FT SILO WITH CORN SILAGE




Lateral or outward
Vertical or downward
Pressure (pounds per sq. ft.)
Depth of silage (feet above bottom of panel)
Time (days after filling)

concrete stave silo was filled with a mixture of oats and peas to which about 40 lb of molasses were added for each ton of green material.

The pressure setup was the same as described above, except that the pressure panels were 29½x21 in, giving an area of 4.3 sq ft, and the points of support 16 in apart. The supporting rods were calibrated in the mechanical engineering laboratory at Rutgers University and found to give a deflection of 0.0001 in for each 1.73 lb of load.

To allow for the weight of the door, zero readings were taken on each rod when a door was placed in the silo, and load readings were taken when the silage was level with the top of each door. Readings were also taken in the morning before filling was resumed to get the effect of settling on the pressures.

The silo was filled from July 6 to 19 and refilled July 20 and 21. The total content weighed 267.8 tons—262.6 tons of green material and 5.2 tons of molasses. The average moisture content of the oats and peas after the molasses was added was 71.9 per cent and ranged from 68 to 79 per cent. Silage juices and molasses drained from the silo doorway and through a few cracks in the bottom 5 ft of the silo for two or three weeks after the filling was completed. Settling went on until December 15 when the silo was opened and the silage was fed out till about the middle of August of this year.

During the past summer a 12x43-ft silo was equipped with pressure panels, and pressures were taken while it was being filled with 157.5 tons of grass silage, consisting of approximately 36 tons alfalfa and molasses silage, 85 tons of sweet clover, and 37 tons of oats and peas. The moistures ranged from 69 to 81 per cent, and averaged 78 per cent. Fig. 7 shows graphically the horizontal and vertical pressures on the 16 panels in both the 18 and 12-ft silos in pounds per square foot when they were full. Here too, as with corn silage, the pressures increased by different amounts, but as the head increased the horizontal pressure increased. The lack of uniformity in the increase of pressure for equal increments of silage, we believe to be due partially to one door taking part of the load of the one above or below it and partially to differences in the moisture content of the different layers of silage.

The pressures in the 12-ft diameter silo are represented in the figures by the broken line curves with the corresponding solid line curves referring to the 18-ft silo. The distinct break in each curve may be due to the different material, moisture, and a varying amount of compaction. The bottom 25 ft of the silo was filled with alfalfa containing 69 to 77 per cent moisture. Above that depth sweet clover and alfalfa containing 80 per cent moisture was added. At this point the pressures on panel No. 1 jumped from 373 to 628 lb per sq ft with the addition of just enough silage to raise the level of the silage from a 23½-ft level to the 27½-ft level. However, the pressure when the silage had settled to 23½ ft was 500 lb and when refilled to a 25-foot head was 537 lb per sq ft. The silo had been filled to 25 ft one evening, settled to 23½ ft, and was refilled the following morning to a depth of 27½ ft. Curves of the vertical pressures show the same characteristics.

Curves plotted from the average pressures on all panels supporting the same head with the average pressures on panels 1 to 16 during settling, also curves of the pressures on panel 1 as the head increased, are shown in Figs. 8 and 9. These curves all follow the same general slope. The curve for the horizontal pressures on panel 1, as the head increases, approaches the straight line increase of 19 lb per sq ft for each foot of depth. The vertical pressures do not appear to be quite so uniform. They show an approximate average of 8 lb per sq ft per foot of depth for depths up to 25 ft and 6 lb per sq ft per foot of depth for depths from 25 to 42½ ft.

During unloading the horizontal pressures showed a slight tendency to increase but not enough to produce loads as great as during the first week of settling. As in the case of corn silage the vertical pressures on the top four or five panels started to go down, and the top and second panel pressures became negative. The reversed pressure lifted the door and gave upward measurable pressures to 225 lb. This indicated load was measured after all the lost motion in the panel supports was taken up and was actually greater.

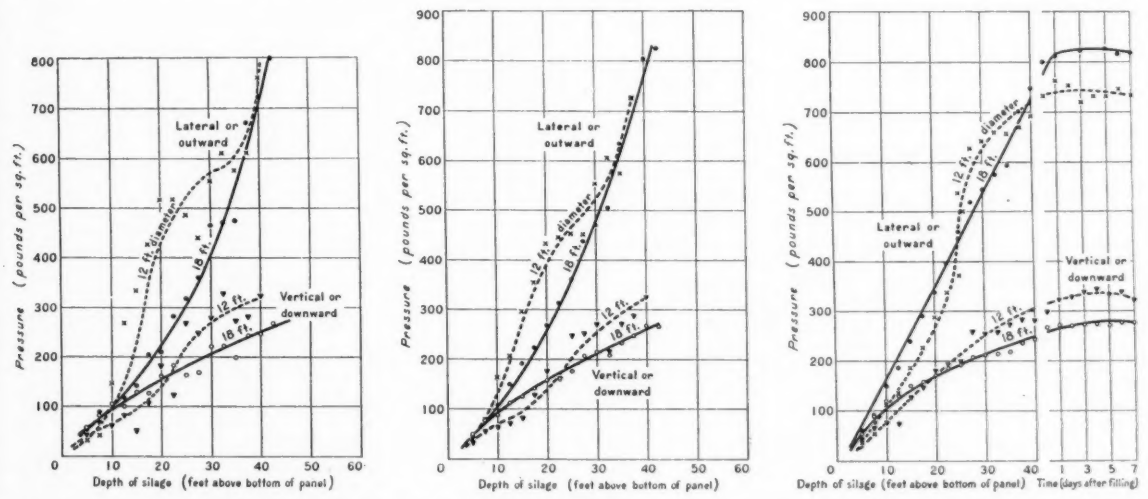


FIG. 7 (LEFT) PRESSURES ON PANELS NOS. 1 TO 16 WHEN SILOS WERE FULL. THE 18-FT DIAMETER SILO WAS FILLED WITH 71.9 PER CENT MOISTURE GRASS SILAGE AND THE 12-FT WITH 78 PER CENT MOISTURE GRASS SILAGE. FIG. 8 (CENTER) AVERAGE OF ALL PANELS HAVING THE SAME DEPTH OF SILAGE ABOVE DURING THE FILLING PERIOD AND 9 DAYS OF SETTLING. THE 18-FT DIAMETER SILO WAS FILLED WITH 71.9 PER CENT MOISTURE SILAGE AND THE 12-FT, 78 PER CENT MOISTURE SILAGE. FIG. 9 (RIGHT) PRESSURES ON PANEL NO. 1, THE BOTTOM PANEL, AS THE DEPTH OF SILAGE INCREASED. THE 18-FT DIAMETER SILO WAS FILLED WITH 71.9 PER CENT MOISTURE SILAGE AND THE 12-FT, 78 PER CENT MOISTURE SILAGE

The moisture content records of the silage when fed out of the 18x43-ft silo were incomplete, and we cannot give very complete figures on the density of settled grass silage at this time. Such densities will vary with the different materials used to fill a silo. When the average density of the silage was corrected for moisture loss, it amounted to 45.7 lb per cu ft with the silo full; 48.8 and 55.5 lb per cu ft when settled one week and one month, respectively. The density of the bottom 6, 10, and 12 ft were 65.1, 63.7, and 63.5 lb per cu ft.

Temperature Studies. When molasses silage investigations were initiated at the New Jersey station in 1934, it seemed advisable at that time to observe the temperature developed in low-moisture silage as compared to high-moisture silage. Lately this work has been expanded to include comparison of temperatures in molasses silage and phosphoric acid silage.

The early temperature study was reported in the Journal of Dairy Science, February 1936, vol. 19, no. 2. In this test, 30 tons of green material, consisting of good alfalfa and mixed grasses at an average moisture content when ensiled of 66.8 per cent, was placed on top of some corn silage of the previous year. On top of this high-moisture silage was placed approximately 16 tons of similar material at an average moisture content of 44.4 per cent. Molasses was added at the rate of 40 lb per ton of green material as ensiled. Filling was completed on October 9. Five iron-constantan thermocouples were placed at various heights in each layer. Temperatures were read twice daily for 19 days after filling and at greater intervals until the silage was fed out the following March and April.

After 17 days the temperature range in the low-moisture silage was from 115 F (deg Fahrenheit) near the center to 144 F near the top. For nearly a month after this the temperatures showed a downward trend, but during the latter part of November they started up and were still going generally upward when the silos were opened March 10. The maximum temperature recorded was 160 F. All thermocouples indicated temperatures of over 130 F at some time. Most of the silage in this section was unfit for feeding, much of it was brown in color, some of it black and charred.

The maximum temperature of 109 F in the high-moisture section was reached about 5 weeks after filling. This was near the center of the mass. From November 15 the temperatures were generally downward. It is certain that this maximum temperature is well below the allowable maximum, but it has been impossible to find a report of any tests that indicate the temperature above which serious losses occur in the food value of the silage. Investigators at the New Jersey station are of the opinion that temperatures below 140 F are safe.

Supplementing the New Jersey investigation of 1934, a test was started in June 1938 to measure the temperatures developed in molasses silage as compared with phosphoric acid silage. Two 14x30-ft silos are being used for the test. One was filled with 78.49 tons of green timothy with molasses added at the rate of 104.13 lb per ton of green material. The second was filled with 81.44 tons of green timothy with 16.28 lb of phosphoric acid per ton of green material. Five thermocouples were placed in each silo 5 ft from the silo wall and at 5-ft intervals with the last thermocouple about 6 ft from the top of the silage. The molasses silage was ensiled on June 13 to 16, the phosphoric acid silage on June 15 to 20. Temperature readings were taken daily for 19 days after filling, then at less frequent intervals. The maximum recorded temperature of 113 F in the molasses silage was reached on June 24. This occurred 10 ft from the bottom of the silo. The minimum of 103 F at that time occurred 5 ft from the bottom of the silo. In the acid silage the temperature reached 108 F at the top thermocouple but only 90 F at the center thermocouple on June 25. After reaching the maximum, the temperatures at all points, except the top in both silos, have moved generally downward. After 9 weeks the temperature at the top thermocouple in both silos has leveled off at 103 F while the temperatures at the other four points in both silos ranged between 83 and 91 F. Readings will be continued until the silos are opened sometime during the winter. These observations indicate that, while the temperature in the molasses silage is slightly but not significantly higher than acid silage, it has never reached a point in either the molasses or acid silage where loss in food value is likely to occur due to heating.

SUMMARY

1 Corn silage put up in the late milk or early dent stage when the moisture content ranges from 68 to 72 per cent was found to exert lateral pressures of 8 lb and vertical pressures of 5 lb per sq ft for each foot of depth in silos of 14-ft diameter.

2 Corn silage in an 18-ft silo with 74 per cent average moisture exerted lateral pressures up to 14 lb and vertical pressures of about 8 lb per sq ft per foot of depth.

3 Grass silage put up with molasses exerted lateral pressures of 19 lb or more and vertical pressures of from 6 to 9 lb per square foot per foot of depth when placed in an 18-ft silo with not more than 72 per cent average moisture, or in a 12-ft silo with not more than 80 per cent moisture.

4 Moisture content of the silage and the diameter of a silo affects the amount of lateral and vertical pressures. Further tests must be run to show the effect each has on the pressures.

5 Temperatures in low-moisture grass silage are apt to go high enough to spoil the silage unless special measures are taken to exclude the air, such as applying weights of about 40 lb per sq ft to the top of the silage.

An Approach to the Study of Flood Peak Formation

(Continued from page 226)

of rainfall stations are available, the limiting area for each rainfall station can be determined by the Thiessen method. Once the Horton-Thiessen weights are established they can be applied to the rainfall over the offending area for a determination of the volume of flow that can be expected by an application of the principles involved in the use of the integration method. Of course, several trials with the prediction of historical floods will have to be made to determine the value of the constants.

A greater number of recording rainfall gages are being installed, giving the actual beginning, intensity, and end of rainfall, thus adding to the usefulness of the integrating method, and there is little doubt that it will soon become an important instrument in the reproduction of flood hydrographs. It is regretted that the authors have not the opportunity to furnish the tabular and graphic evidence of the accuracy of the method at this time. Without doubt the adaptability of this method is being awaited with interest by the engineering world. Meanwhile the authors or the writer of the above comments will be glad to be of assistance in developing applications of the integration method in particular localities.

Pneumatic Tractor Tire Profile Studies

By R. H. Wileman

USE of low-pressure pneumatic rubber tires on farm tractors has become a quite generally accepted practice. One of the major problems of the tire and tractor engineer now is to develop treads and tire profiles which will further improve the efficiency of the rubber tire for farm tractor use and to change the tractor so it can take full advantage of this type of wheel equipment. The problem of working out a tread design and a tire profile which will give satisfactory results in various soils and under various soil conditions is one of no small proportions.

During the 1938 season studies of the relative efficiencies of three types of rubber tractor tires were made by the Purdue University agricultural experiment station. The tires used for this study consisted of the regular tractor tire with a bar tread, the high-lug or rice-field tire, and an experimental "low-profile" tire. For the benefit of those who are not familiar with the low-profile tire, its cross section is about the same as would be obtained by cutting the side walls of a regular tire at the point of maximum width and attaching the beads at these points. This results in a tire having a depth equal to about one-half its width. This type of tire profile enables the use of a larger rim diameter, which makes possible a wider range of tread widths on some tractors, without using a tire with an excessive overall diameter.

These three types of tires were compared with regular steel wheel and lug equipment to determine their relative efficiencies for traction, fuel economy, rolling resistance, and adaptability in performing different field operations. The tests were made performing regular field operations on Crosby, Clyde, and Brookston soils, or clay and black soils. Fuel tests were made on a two-acre area in each case and run in duplicate. The tractors were operated in the gear which gave a drawbar load as near rated capacity as was practical for the load being pulled. All conditions under which the tests were made were kept as nearly comparable to average farm operating conditions as possible.

Presented before the Power and Machinery Division at the fall meeting of the American Society of Agricultural Engineers, at Chicago, Ill., November 29, 1938. Mr. Wileman (Mem. A.S.A.E.) is assistant professor of agricultural engineering at Purdue University.

HIGH-LUG OR RICE-FIELD RUBBER TIRES PULL A PLOW THROUGH LOOSE, SOFT MUCK SOIL WHERE STEEL WHEELS WITH SPADE LUGS WERE HELPLESS, ORDINARY RUBBER TIRE TREADS LACKED SUFFICIENT TRACTION, AND HORSES NEEDED MUCK SHOES TO PULL EFFECTIVELY

Rolling resistance was determined at the same speed as was obtained during the test of each type of wheel equipment. This should be remembered when comparing the various types of wheel equipment, as the rolling resistance of one might be higher than another, yet the actual pounds pull could be less due to the difference in speed.

Table 1 gives the results obtained with the different tire equipment in plowing sod ground with two and three-plow tractors.

In making these tests 300 lb of wheel weights were used on each wheel for all tests.

It will be observed that the regular tire shows up better in these tests than did either the low-profile or the rice-field tire.

The ground was unusually dry for spring plowing last season, which resulted in high draft of the plow and little penetration of the tire tread. For this reason the high-lug tire was at a disadvantage, as its area of contact with the soil was comparatively small, only partial lug penetration being obtained.

Higher inflation pressures, ranging from 18 lb upward, depending on the amount of wheel weights used, are recommended for the low-profile tire. The higher inflation pressure combined with the shallow side walls materially reduces the flex of the tire, resulting in a smaller soil contact area and poorer conformity with the soil surface.

From the results shown by these data, and observations made during the tests, it is apparent that the rubber tire must have ability to flex to conform to the soil contour, and for best results the lug height should not exceed the point where it will penetrate sufficiently to allow the body of the tire to be in contact with the soil.

Table 2 shows the results of similar tests made with three-plow tractors using the same wheel equipment and pulling a 10-ft tandem disk and a 10-ft soilpacker.

In disking sod ground, as in plowing, the regular tire gave the best results. On this type of soil, where sufficient traction could be obtained by the regular tires, the high-lug or rice-field tire was at a decided disadvantage, as its rolling resistance was much higher than for the other rubber tires, although its speed of travel was slower. With this tire the tractor had to be operated one gear slower than with the other rubber tires, or in the same gear as with steel wheels and lugs. Here again the low-profile tire showed its lack of ability to flex and give as good contact with the soil as did the regular tire. Difficulty from excessive slippage was experienced with these tires while disking. Two or three times during the test it was necessary to straighten the disk before it could be moved.

In disking cornstalk ground the regular and low-profile tires were the only ones used. Here but little difference is shown in the efficiency of the two types of tire equipment. This can be at least partially explained by the better tractive conditions and by the lighter drawbar load.

Our data indicate that for the type of soil and field conditions encountered throughout most of Indiana, with the exception of the loose sands or muck, the conventional type of rubber tractor tire gives the best results under average farming conditions.

A series of tests were made to determine the tractive

TABLE 1. DATA FOR TWO AND THREE-PLOW TRACTORS WITH VARIOUS WHEEL EQUIPMENT PULLING PLOWS 7 IN DEEP (PLOWING SOD)

Size of tractor	Wheel equipment used	Load used	Average drawbar horsepower	Average rolling resistance of tractor	Total engine load, hp	Operating speed, mph	Fuel, gal per acre	Fuel, per cent of steel	Fuel saving compared to steel, per cent
2-plow	Steel wheels spade lugs	2-14-in plow	10.78	5.83	16.61	3.38	2.46	100.0	——
2-plow	10.00x36 bar-tread rubber tires	2-14-in plow	13.05	2.62	15.67	4.18	2.04	83.0	17.0
2-plow	10.00x36 rice field type rubber tires	2-14-in plow	12.43	2.35	14.78	3.73	2.20	89.5	10.5
3-plow	Steel wheels, spade lugs	3-14-in plow	15.60	9.06	24.66	3.27	2.31	100.0	——
3-plow	11.25x36 bar-tread rubber tires	3-14-in plow	20.80	2.75	23.55	4.21	1.88	81.4	18.6
3-plow	12.00x40 low-profile rubber tires	3-14-in plow	19.05	3.84	22.89	4.09	2.11	91.4	8.6
3-plow	10.00x36 rice field type rubber tires	3-14-in plow	18.48	4.37	22.85	3.82	2.07	89.6	10.4

TABLE 2. SEEDBED PREPARATION—THREE-PLOW TRACTOR PULLING 10-FT TANDEM DISK AND 10-FT SOILPACKER

Size of tractor	Wheel equipment used	Type of ground worked	Average drawbar horsepower	Average rolling resistance of tractor	Total engine load, hp	Operating speed, mph	Fuel, gal per acre	Fuel, per cent of steel	Fuel saving compared to steel, per cent
3-plow	Steel wheels, spade lugs	Fall-plowed sod	16.40	8.82	25.22	3.15	0.843	100.0	——
3-plow	11.25x36 bar-tread rubber tires	Fall-plowed sod	19.35	5.78	25.13	3.83	0.62	73.6	26.4
3-plow	12.00x40 low-profile rubber tires	Fall-plowed sod	18.60	5.12	23.72	3.55	0.74	87.8	12.2
3-plow	10.00x36 rice field type rubber tires	Fall-plowed sod	17.20	7.21	24.41	3.38	0.765	90.8	9.2
3-plow	11.25x36 bar-tread rubber tires	Cornstalk ground, 1st disking	14.76	——	——	4.50	0.50	*100.0	*0.0
3-plow	12.00x40 low-profile rubber tires	Cornstalk ground, 1st disking	17.10	——	——	4.42	0.50	*100.0	*0.0
3-plow	11.25x36 bar-tread rubber tires	Cornstalk ground, 2nd disking	14.93	——	——	4.03	0.419	*100.0	*0.0
3-plow	12.00x40 low-profile rubber tires	Cornstalk ground, 2nd disking	14.45	——	——	4.09	0.391	* 93.4	*6.6

*These are based on the two types of tires tested under these conditions. The highest fuel consumption being taken as 100 per cent.

ability of the rice-field or high-lug rubber tire in very loose muck soil conditions. It was found that this type of tire would operate and have sufficient traction to pull drawn equipment under very adverse muck soil conditions. Using a small tractor equipped with 10.00x36 rice-field tires, we were able to plow and prepare a seedbed where a tractor equipped with steel wheels would mire down and rubber tires having the low-bar type of tread did not have sufficient traction. The muck soil in which these tests were made is so soft and loose that horses can not be used on it unless they are equipped with muck shoes. Dual tires of the rice-field type were also tested but do not seem necessary on the smaller tractors. Experience indicates that under this type of soil conditions they are advantageous on three-plow or larger tractors. From the experiences encountered during these tests it seems that the rice-field or high-lug rubber tire will make it possible to use wheel-type tractors under loose, soft, and wet soil conditions where they have previously failed because of excessive slippage and miring down.

Voids in Granular Materials

By W. P. Berggren

HOW MANY beans in the jar? This question and important related ones may be answered with reasonable precision. The closeness of packing in granular materials has received brief attention in several fields of study. In nearly all cases the problem has been treated as peculiar to the field and the opportunity for application of geometric similarity has been overlooked.

A cement mill operator asks, "How many 2-in balls can be packed into a cubic foot?" If we take the cubic foot literally to be a box one foot on a side, it is obvious that rectangular stacking will admit exactly 216 (6x6x6) balls of total volume $\pi/6$ cu ft, leaving 47.64 per cent voids (unoccupied volume). If the balls are simply dumped into the box, it is almost certain that fewer will be admitted; hence a higher "percentage of voids". But if we think, as did our correspondent, in terms of a ball mill 8 ft in diameter and 50 ft long, the 2-in balls may be considered grains, and the solution is found by dropping small shot into a graduated glass cylinder. Several experiments of this type, keeping the grain size less than one-tenth of the container diameter, result in voids of 42 to 45 per cent. If the shot are dropped in singly, or shaken down, the voids may be reduced to 38 to 40 per cent. This apparent "limit of compactness" is not to be confused with the perfectly packed system of equal spheres, which includes only 25.95 per cent voids, as demonstrated below.

The available data on packing of smooth solids approximating spheres or spheroids shows more uniformity than one might expect. Average voids in rice[1] are given as 48 per cent, and in walnuts[2] 44 to 45 per cent, with void *areas* about 36 per cent (measured by pouring molten paraffin into container of walnuts and cutting cross sections). A good approximation to the void area[3] is obtained from the geometric relation

$$\frac{100 - \%\text{ void area}}{100} = \left[\frac{100 - \%\text{ void volume}}{100}\right]^{2/3}$$

Measurements on sand, gravel, and broken coal from a number of sources give void volumes from 40 to 50 per cent, depending not so much upon coarseness as upon range of particle size. Obviously a mixture of large and small particles should pack better than either single component[4]. However, broken iron ores, consisting of more or less jagged particles, range in voids from 52 to 65 per cent[5]. In contrast, hand-packed apples[6] run 30 to 35 per cent voids.

The perfectly-packed system of equal spheres is an arrangement in which each sphere is tangent to twelve others. If we express the solid-volume and total volume by v and V, respectively, the "solid ratio" will be v/V and the void-ratio will be $1 - v/V$.

A single sphere inscribed in a cube has a solid-ratio

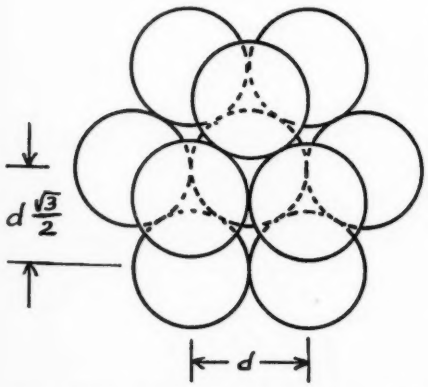
$$\frac{v}{V} = \frac{\frac{\pi d^3}{6}}{d^3} = \frac{\pi}{6}$$

Hence the void-ratio for this elementary case is

$$1 - \frac{\pi}{6}, \text{ or } 47.64 \text{ per cent} \qquad [1]$$

The same value of course applies to a rectangularly-packed system in which each sphere is tangent to six others.

Fig. 1 illustrates the arrangement of twelve spheres tangent to a central one in the perfectly packed system. Six are tangent to the central one in a common plane, as pennies would be arranged on a table. Three more lie in a plane whose altitude (the four-ball problem of solid geometry) above the first plane is $d\sqrt{2/3}$, and the last three



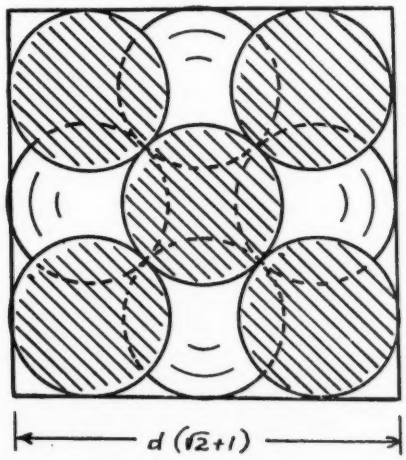


FIG. 1 (ABOVE) A CLUSTER OF EQUAL SPHERES IN A PERFECTLY PACKED SYSTEM. FIG. 2 (RIGHT) A FACE-CENTERED CUBE

Prepared especially for AGRICULTURAL ENGINEERING. Dr. Berggren is junior physicist in the agricultural experiment station, University of California.

[1]Stirniman, Bodnar, and Bates. "Resistance to Passage of Air through Rough Rice," AGRICULTURAL ENGINEERING, 12 (5):145, May 1931.

[2]Soomil, E. Y. "Flow of Air through Walnuts," unpublished report on graduate research submitted (1936) to B. D. Moses, division of agricultural engineering, University of California.

[3]Furnas, C. C. "Flow of Gases through Beds of Broken Solids," U. S. Bureau of Mines Bulletin 307, 1929, p. 20.

[4]Furnas, loc. cit, pp. 75-82.

[5]Furnas, loc. cit, p. 31.

[6]Allen, F. W. "Apple Growing in California," California Agricultural Experiment Station, Bulletin 425, May 1927, Rev. May 1937, pp. 60-68.

of course lie the same distance below. Since these thirteen balls just fit into a sphere of diameter $3d$, the solid-ratio is

$$\frac{v}{V} = \frac{13\frac{\pi d^3}{6}}{\frac{\pi (3d)^3}{6}} = \frac{13}{27}$$

and the void-ratio for the cluster

$$1 - \frac{13}{27} = \frac{14}{27} = 51.85 \text{ per cent} \qquad [2]$$

Although this value is higher than that for rectangular packing, it will be shown that an indefinite extension of the elementary cluster gives the void-ratio quoted above for a perfectly packed system.

Suppose the arrangement of Fig. 1 be extended so that the plane now containing seven spheres contains n rows ($d\sqrt{3}/2$ apart) of n spheres (d apart) each and that there are n similar planes $d\sqrt{2/3}$ apart). There will now be a total of n^3 spheres occupying a volume

$$V = nd\frac{\sqrt{3}}{2} \times nd \times nd\sqrt{\frac{2}{3}} = \frac{n^3 d^3}{\sqrt{2}}$$

The solid-volume is

$$v = n^3 \times \frac{\pi d^3}{6}$$

and the solid-ratio

$$\frac{v}{V} = \frac{\frac{\pi}{6} n^3 d^3}{\frac{n^3 d^3}{\sqrt{2}}} = \frac{\pi}{6}\sqrt{2}$$

giving the void-ratio

$$1 - \frac{v}{V} = 1 - \frac{\pi}{6}\sqrt{2} = 25.95 \text{ per cent} \qquad [3]$$

The perfectly-packed system may also be built up from a series of planes containing rectangular arrangements of spheres. These planes of course occur obliquely in the system just described.

The elementary face-centered cube of Fig. 2 contains 14 spheres. The side of the cube is

$$L = d\,(\sqrt{2} + 1)$$

in which d again represents the sphere diameter. The solid-ratio will be

$$\frac{v}{V} = \frac{14\frac{\pi d^3}{6}}{d^3(\sqrt{2}+1)^3} = \frac{7\pi}{3(\sqrt{2}+1)^3}$$

Hence the void-ratio is

$$1 - \frac{7\pi}{3\,(\sqrt{2}+1)^3}, \text{ or } 47.90 \text{ per cent} \qquad [4]$$

It is of interest to note that the face-centered cube gives a slightly higher void-ratio than a single sphere (or a rectangular arrangement). However, an indefinite extension again gives the perfectly packed system described above. By building on the arrangement of Fig. 2 one may observe the decrease of the void-ratio, and finally show that the value of equation [3] is approached as the number of spheres becomes indefinitely large.

Extending the system until each edge of the cube has n spheres (instead of two, as in Fig. 2), we find the side of the cube to be

$$L = d\left[(n-1)\sqrt{2} + 1\right]$$

The total volume is

$$V = L^3 = d^3\left[(n-1)\sqrt{2} + 1\right]^3$$

The total number of spheres:

$$N = n^3 + 3n\,(n-1)^2$$

Solid-volume:

$$v = \frac{\pi d^3}{6}\left[n^3 + 3n(n-1)^2\right]$$

The solid-ratio becomes

$$\frac{v}{V} = \pi \frac{\frac{2}{3}n^3 - n^2 + \frac{n}{2}}{2\sqrt{2}n^3 - 6(\sqrt{2}-1)n^2 + 3(3\sqrt{2}-4)n + 7 - 5\sqrt{2}}$$

As n becomes indefinitely large, the value of the fraction approaches the ratio of the n^3— terms.

Hence $$\lim_{n \to \infty} \frac{v}{V} = \pi \frac{\frac{2}{3}}{2\sqrt{2}} = \frac{\pi}{6}\sqrt{2}$$

and the minimum void-ratio again is

$$1 - \frac{\pi}{6}\sqrt{2} = 25.95 \text{ per cent} \qquad [5]$$

The decrease of void-ratio as the face-centered cube of Fig. 2 is extended to contain N spheres (instead of 14) and n along each edge (instead of 2) is summarized below.

VOID RATIOS FOR EXTENSION OF FACE-CENTERED CUBE

n	N	Per cent of voids
1	1	47.64
2	14	47.90
3	63	41.21
4	388	37.50
10	3430	30.58
100	3,940,300	26.41
∞	∞	25.95

This seed-crop windrower is used for alfalfa seed harvesting in southern Idaho. This machine transfers the seed crop from the sickle of the mower into an even windrow, reducing shatter. It is operated by a power take-off from the tractor and consists essentially of two platform drapers carried on 18-in caster wheels

New Machinery Developments Needed in Southern Agriculture

By H. P. Smith

THE cotton belt has long been looked upon primarily as a region of small farms which are poorly equipped mechanically. In a way, I feel that the implement companies, or at least the implement dealers, are partly responsible for the continued general use of one-mule tools in many sections of the cotton belt. For example, a few years ago the Texas agricultural extension service arranged with several implement companies to demonstrate planters and cultivators at different locations in the piney woods section of East Texas. After watching a riding planter knock off the top of the bed, drill the seed, and fertilize and cover them in one operation, some of the farmer spectators were heard to make such remarks as: "Isn't it wonderful?" "Who would have thought it possible?" The kind of implements used in a community depends to a large extent on what the implement dealer has for sale and his desire to sell it.

Southern farmers are interested in better farm machinery—machinery that will help produce crops at a minimum cost, and combat grass, weeds, and insects. This fact is emphasized by C. H. Hamilton, an economist in rural life of the Texas agricultural experiment station, who says: "Although the greatest degree of mechanization is found in the north central states, we must look elsewhere to discover the higher and more spectacular rates of mechanization. . . . . Although the old cotton states of the South still have few tractors compared with the North and West, they all show high rates of mechanization." With this trend toward mechanization, the southern farmer is interested in obtaining simple machinery suited to the crops grown, topography, size of farm, and soil types.

What, then, are some needed improvements in southern farm machinery?

Cotton is the principal crop of the South and the least mechanized of any crop grown in the nation on such a large scale. Such crops as wheat, oats, and corn may be planted, cultivated, harvested, and placed on the market hardly touched by human hands, but not cotton.

For generations enormous quantities of cottonseed have been drilled along the rows and the large number of seedlings thinned to a single stalk stand by chopping with a hoe. Experiments have shown that by hill dropping, fewer seed are required and time and cost of thinning are reduced. The ordinary hill-dropping device drops a large number of seed per hill, yet I believe a hill-dropping device that will select and drop 3 or 4 seed per hill would be a decided improvement and would still further reduce the quantity of seed required and practically eliminate the necessity of thinning.

In Northwest Texas, where two-row lister planters are used, the farmers have trouble getting the planters to cover every row to a uniform depth. For example, two rows will be covered to an optimum depth, while the next two rows will either be covered too shallow or have no seed planted. It appears that a better "knee-action" device is needed for the planter drive and better means of adjusting the depth to obtain good coverage of seed.

During the past few years many experiments have shown the value of placing the fertilizer to the side of and below the level of cottonseed. It appears that the implement manufacturers have been slow in developing adequate attachments for planters that will fit this need. Attachments should be developed that will fit planters already in use.

One correspondent states that there is a need for a satisfactory cotton and corn planter for the one-plow tractor in the cotton belt. The planter should be directly mounted and have the necessary equipment for making seedbeds or water furrows, placing the seed and fertilizer all in one operation.

If a satisfactory hill-dropping device is not developed and large quantities of cottonseed are sown, there still will be a need for a mechanical cotton chopper.

Most fields throughout the cotton belt are enclosed by fences, and it is often difficult to steer the cultivator out to the end of the row without injury to the last two or three plants. One implement manufacturer has designed a one-

Presented before the Southern Section of the American Society of Agricultural Engineers at New Orleans, La., February 2, 1939, and approved as Popular Contribution No. 1050 by the Director of the Texas Agricultural Experiment Station. Mr. Smith (Mem. A.S.A.E.) is chief, division of agricultural engineering, Texas Agricultural Experiment Station.

ALTHOUGH THE SOUTH IS BEHIND THE NORTH CENTRAL AND OTHER IMPORTANT AGRICULTURAL AREAS IN MECHANIZATION OF ITS FARMS, IT IS GAINING WITH A MORE RAPID RATE OF MECHANIZATION. ITS CLIMATE, CROPS, SOILS, AND ECONOMIC AND SOCIAL CONDITIONS IMPOSE SPECIAL PROBLEMS IN MECHANIZATION, THE SOLUTION OF WHICH WILL ENCOURAGE FURTHER PROGRESS

row, two-mule walking cultivator with pivot wheels which enables the operator to keep the cultivator in line with the plants after the team has begun to turn along the fence. He claims it is easy to follow sharply curving rows and to plow close to stumps with this cultivator. This tool should be popular in many sections.

A Texas agricultural experiment station superintendent suggests that flanges should be placed on all planter and cultivator wheels to help hold the implement on the sides of terraces.

Federal and state authorities in Texas are very much concerned about the pink bollworm situation. The urgent need today is a cheap, simple, and efficient stalk cutter or burner. A cutter to meet their requirements should sever the stalks just below the ground surface without agitating the plant to the point of shattering the burs and dry immature bolls infested with worms. The present method of cutting cotton stalks is largely with a machete. One man can cut about three-fourths of an acre a day with this tool. An asbestos-lined hood fitted with several burners would probably burn or ignite the cotton debris and be more efficient as a clean-up measure than cutting, piling, and burning the stalks.

So much has been written about the mechanical cotton harvester that I hesitate to mention it in this paper. Many efforts have been made to perfect a cotton harvester that will do the work of human hands. Well-designed machines have been built, but the characteristics of the cotton plant prevent them from being highly efficient. At least they are not sufficiently efficient under all field conditions for the cotton grower to accept them under present economic and social conditions. You may ask under what conditions will the cotton grower accept the mechanical cotton harvester. A prediction along this line would be like trying to predict where lightning will strike, but I wish to present this thought. The trend in mechanization clearly shows that many laborers—yes, many families—are being forced off the farm. When this continues to the point where there is not sufficient labor to harvest the cotton crop and transient labor becomes highly organized, a situation may develop that will force the cotton farmer to use mechanical means to harvest his cotton crop. When this time arrives, the cotton farmer will no doubt practice cultural methods and select varieties of cotton that will be more suitable to machine harvesting.

Sweet potatoes are also grown extensively throughout the South, and with the development of starch production from the sweet potato there is need for better equipment for the planting and digging of the potato. Already the U. S. Department of Agriculture has a man working on improvement of machinery for harvesting sweet potatoes. My attention has been called to the need of a sweet potato burnishing machine which will handle the various sizes and shapes of potatoes without bruising or cutting them. This machine should be constructed so that excessive amounts of dust will be eliminated.

In Texas large acreages of sorghum are grown for grain, and the majority of the heads are harvested by cutting them off with a pocket knife. A few grain-sorghum heading machines are available and some combines are used, but it appears that there is room for the development of a simple and inexpensive header, probably as an attachment for a tractor.

Also there seems to be need of a machine for drying peaches that have been gathered during rainy weather. Ordinarily the fuzz adhering to the surface of the peach is removed before it is packed, and it is difficult, or almost impossible, to remove this fuzz when the peaches are damp. The surface moisture, therefore, needs to be removed by a drying process before the peaches are brought to the defuzzing machines.

In connection with the tung oil industry that is being developed along the Gulf Coast it has been mentioned that an efficient shelling machine would be of considerable help in removing the outer husks and leaving the unbroken seed for removal to the nearest point for crushing and extraction of the oil. At present the whole nuts, husks and all, are gathered and carried to the crushing plant where the shelling is done. A portable shelling machine would leave the husks in the orchard.

The whole nation is interested in soil conservation, and there is need for improvement of machines for use in terraced fields. Planters and cultivators should be flexible enough to follow uneven surfaces and constructed so they will not slide down the sides of the terraces. Orchards where the trees are set on the terraces need cultivating equipment that will maintain the terraces, such as some type of disk plow with an offset hitch to permit working under the low limbs and close to the tree. Another machine needed for orchards is a low-set drill to permit seeding winter crops under the trees. Such machines should be useful in tung tree orchards.

Terracing experts have been wishing for a machine that would build a terrace in one trip across the field. Probably if someone would try rigging up some ditch-digging buckets, or a rotating wheel with cutting blades to cut across the terrace channel, they might do the job. Such a device could be used as a tractor attachment. One suggestion received was that terrace construction would be aided materially by the development of a reversible long-wing plow which would facilitate the construction of the channel type terrace, as this terrace is constructed, in the main, from the upper side.

There is widespread interest in the collection of various kinds of pasture grasses and clover seed so that they can be distributed on pasture lands or lands that have been taken out of cultivation and put into pasture. Probably some kind of suction device attached to a tractor that would pick up the seed and convey them to a small combine which would clean them might be developed.

The lespedeza seed harvester now in use saves only about 45 per cent of the seed and a more efficient machine for this purpose would be welcome. I would like to see someone try a spiral spike beater mounted above a screen somewhat on the order of the auger conveyor used on one make of combine. The beater in this case, however, should be enclosed, except along the front where hay could enter. The beater would need to be a foot or so longer than the cutter bar and could be driven by a sprocket attached to the outside of the mower wheel. The spiral beater would serve both as a threshing beater and as a conveyor which would discharge the hay at the outer end.

Because of the high rainfall throughout the cotton belt, the production of good hay is hazardous, and it is the dream of many that some day a portable low-cost and efficient artificial hay drier will be developed.

These are only a few of the many needed improvements that could be cited. They are sufficient, however, to show the wide field open in the South for experimental work on the part of both the manufacturer and the state agricultural experiment stations.

Supplementary Irrigation in the Central States

By Virgil Overholt

A STUDY of the mean rainfall in Ohio during the growing season will show about 0.8 in per week, which is just about optimum for most crops grown in the state. Unfortunately, however, the distribution of this rainfall is far from uniform and is absolutely unpredictable.

A study of data taken from the weather station at Sandusky, Ohio, illustrates this point. The mean monthly rainfall (over a 53-year period) for April to September, inclusive, is 19.39 in, or about 0.8 in per week. The total maximum rainfall for these same months is 49.67 in, or 1.9 in per week. The total of the monthly minimum rainfall for the period is 3.35 in, or 0.13 in per week. The total number of days per month with 0.25 in or more precipitation is 3.9.

These extremes of rainfall require adequate means for water control if we are to have optimum soil moisture at all times. To remove the excess moisture, Ohio farmers have invested $35,000,000 in 25,000 mi of public drainage outlets. They have invested far more than this amount in private drainage on their farms. Adequate drainage, by encouraging deep root growth and improving the physical structure of the soil, is of material aid in times of drought. But, due to these great extremes of rainfall, this is not enough for maximum crop growth. Complete water control also requires supplemental irrigation.

The economic importance of supplemental irrigation will depend upon the per acre value of the crop grown and the availability of water for irrigation. In Ohio, irrigation has been limited largely to vegetables, fruits, potatoes, and hybrid seed corn. We do find an occasional farmer who profitably irrigates other field crops. At the present time there is a growing interest in pasture irrigation. Many of our pastures are along streams large enough to furnish an adequate water supply.

The time will probably never come when expensive irrigation structures, such as are found in the West, will be profitable in the east central states. Here the practice will likely be limited to nearby streams, wells, ponds, and springs. One and one-half miles is the greatest distance water is now being transported for irrigation purposes in Ohio, and this is considered extreme.

The question of water rights is not adequately covered by laws in the central states. In anticipation of this need the Ohio Horticultural Society now has a legislative committee at work. A hybrid corn grower in Fairfield County recently discovered that he is not entitled to all the water from a spring in his own front yard. The water from this spring flows as a small stream through a neighbor's pasture. One of our largest fruit growers several years ago sold his river frontage to the local metropolitan park board. In doing so he was wise enough to retain unlimited water rights. He now irrigates several hundred acres of fruit. In another case, a central Ohio fruit grower sometimes stops irrigating before he has applied the desired amount of water. His water supply is from a natural stream. He fears the possibility of some restraining action by the land owners along the same stream below his farm.

Almost every method known has been used in applying irrigation water in Ohio. Overhead spray irrigation was most widely used by vegetable and flower growers in the early days of irrigation. It is still most popular with them and seems likely to continue so. The installation cost is rather high, but this is its only serious disadvantage. Because of the ease of application, growers of high-acre-value crops are willing to pay the price. More acres are irrigated in Ohio by this method than all others put together.

Porous hose irrigation is not used so widely as it was a few years ago. Growers have difficulty in getting uniform distribution and object to the large amount of labor involved. Our heavy soils do not seem to be well adapted to this method of application. Its use is now limited largely to emergency applications.

Waterproof eyelet hose gives better distribution of water with less labor and is still used by some orchardists.

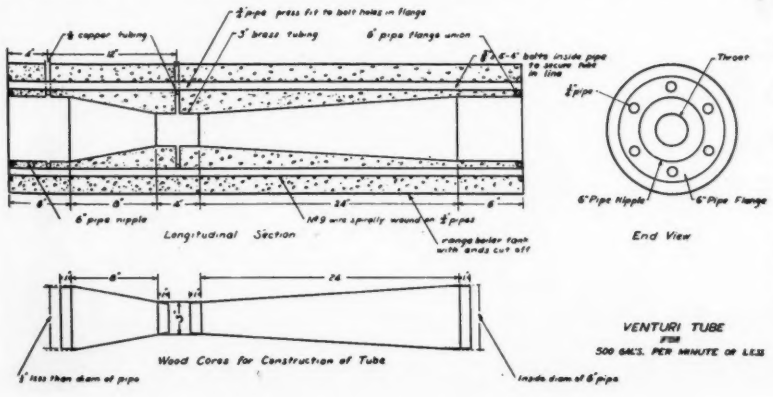
Surface irrigation has never been popular in Ohio. Many of our soils have irregular topography. The surface soil is not deep enough to permit levelling off. Moreover, surface irrigation requires skill and experience. The central states farmer does not apply enough irrigation water to acquire this skill and experience; however, one successful potato grower has followed this method for nine years.

During the past three years there has been an increasing interest in the rotary sprinkler and light-weight pipe. This system seems to be well adapted to more extensive crops that must be rotated from field to field. Wendell Baker of Urbana, Ohio, is equipped to irrigate 100 acres of hybrid seed corn with rotary sprinklers. He has an abundant supply of water any place on his farm at a depth of less than 12 ft. Several Ohio potato growers are irrigating with lightweight pipe and rotary sprinklers.

O. E. Robey, of Michigan State College, is experimenting with a high-pressure rotary sprinkler. A 6 to 10-acre field can be covered from one setting of the nozzle.

Dr. H. D. Brown, on his recent trip to Europe, found high-pressure irrigation nozzles *(Continued on page 252)*

Presented before the Soil and Water Conservation Division at the fall meeting of the American Society of Agricultural Engineers, at Chicago, Ill., December 2, 1938. Mr. Overholt (Mem. A.S.A.E.) is professor of agricultural engineering at Ohio State University.



. . . 7 OUT OF EVERY 10
FARMERS WHO HAVE DECIDED
ON THE TYPE OF TRACTOR
THEY WILL BUY NEXT SAY:
"I HAVE DECIDED TO BUY A
HIGH COMPRESSION TRACTOR"

Have you heard the news?

The big news of the year in tractors can be summed up in few words: 7 out of every 10 farmers who have decided on the type of tractor they will buy next are planning to buy a *high compression* tractor. Forty-three national and state farm magazines established this fact in a recent farm survey made in cooperation with the Ethyl Gasoline Corporation. This shows that farmers everywhere realize that tractors with high compression, gasoline-burning engines give more power, higher efficiency, better warming up and idling and no oil dilution. It looks like a big year for tractor dealers who talk, sell and demonstrate high compression tractors. Are you ready to make it *your* big year? Ethyl Gasoline Corporation, Chrysler Building, New York, N. Y., manufacturer of anti-knock fluids (containing tetraethyl lead) used by oil companies to improve gasoline.

NEWS

A.S.A.E. Cooperates with A.A.A.S. in Soil Conservation Program

AGRICULTURAL engineers in soil and water conservation work will have an opportunity to considerably extend their meeting contacts and studies of their mutual problems by proceeding from the A.S.A.E. annual meeting in St. Paul, June 19 to 22, to a soil conservation program in Milwaukee, Wisconsin, and a four-day excursion trip in Wisconsin to see examples of soil erosion and erosion control works. The Milwaukee meeting and trip is sponsored jointly by the Section on Engineering, and the Section on Geology and Geography of the American Association for the Advancement of Science, and the Soil and Water Conservation Division of the A.S.A.E.

Dr. M. L. Nichols will address this meeting, Friday, June 23, on "Mutual Problems of Conservation — Engineering and Geology." Another agricultural engineering contribution will be "Land Slides in Relation to Agricultural and Engineering Problems," by C. F. Stewart Sharpe, division of research, U. S. Soil Conservation Service.

Other papers and addresses scheduled for this meeting, which begins June 22, include "The Role of the Soil Conservation District in Land Use Planning in Michigan," by Paul M. Barrett; "A Soil Key with Land Use Connotations," by T. M. Bushnell; "Classes of Land According to Use Capability," by Dr. E. A. Norton; "Soil Conservation Problems in the Great Lakes Basin of Ohio, Indiana, and the Lower Peninsula of Michigan," by A. H. Paschall; "The Sheboygan County Land Utilization Research Project," by W. F. Ramsdell; "The Relation of Forest Cover to Soils in the Lake States," by Eugene Roe; "Characteristics of Public Lands in Michigan," by F. P. Struhsaker; "The Soil Conservation Program in Western Canada," by L. B. Thomson; "Wisconsin's Land Use Problems," by A. R. Whitson; and "Land Utilization: Yesterday, Today, and Tomorrow," by Louis A. Wolfanger.

The excursion following the meeting will be led by Dr. E. F. Bean, state geologist of Wisconsin. Places tentatively scheduled to be visited include Mt. Horeb CCC Camp, Tower Hill State Park, Genoa, LaCrosse, Coon Valley CCC Camp, Bangor, Onalaska, Perrot State Park, Melrose, Black River Falls, Dells, Ableman, Weidman Falls, Baraboo, and Devils Lake. This trip is planned to cover in a short time a wide variety of examples of soil erosion and erosion control work. Those desiring to do so may leave the trip either at Dells or at Baraboo.

Advance registration for the trip is desirable, to permit arrangements for bus transportation. The exact cost of the trip has not been determined, and will vary according to the number participating, but has been estimated at $30.

Treasure Island Site for Pacific Coast Section Summer Meet

A ONE-DAY meeting of the Pacific Coast Section, A.S.A.E., has been scheduled for July 25, on Treasure Island, the site of the Golden Gate International Exposition. The program is to be presented in the Pacific House, beginning at 10 a.m.

"The Program of the Regional Salinity Laboratory, Riverside," is to be explained by Dr. O. C. Magistad, director of the laboratory.

"Aims and Objectives of the Western Regional Research Laboratory, Albany," will be presented by R. H. Nagel, acting director. This is one of the new laboratories established to develop industrial uses for agricultural products.

Baldwin M. Woods, professor of mechanical engineering, University of California, will address the Section on "The Necessity for Agricultural Research."

"Organization, Objectives, and Procedure of Flood Control Investigations in California," by E. I. Kotok, director of the California Forest and Range Experiment Station, is the first contribution on the afternoon program.

An illustrated presentation of "Observations on Torrent Control of the Alps Region of Europe" is to be presented by J. D. Sinclair, silverculturist, U. S. Forest Service.

Any and all interested engineers are invited to attend the meeting.

Tennessee Section Organized

AT A meeting of Tennessee members of the American Society of Agricultural Engineers, held at Knoxville, May 9, 1939, it was voted to petition the Council of the Society for recognition as a state section to be known as the "Tennessee State Section of A.S.A.E." The petition was recently approved by the Council, and the officers of the new Section include M. A. Sharp, chairman, C. J. Hurd, vice-chairman, and G. E. Martin, secretary-treasurer.

Georgia State Section Holds Spring Meeting

TWENTY-ONE members of the Georgia State Section of the A.S.A.E. and their wives, lady friends, and other guests attended the spring meeting of the Section at Athens, Saturday, April 29.

Subjects and speakers on the technical program in the morning included "The Place of the Small Tractor and Combine in Georgia Agriculture," by F. W. Peikert; "Small General-Purpose Barns for Georgia," by W. E. Hudson; "An Approach to the Study of Flood Peak Formation," by F. N. Hardisty; "Use of Freezer Lockers," by G. I. Johnson; "Rural Electrification," by George Bell; "Soil Conservation Districts in Georgia," by T. L. Asbury; and informal talks by R. H. Driftmeir and A. Carnes. G. I. Johnson, chairman of the Section, presided.

New officers elected following the technical session were J. C. Oglesbee, Jr., chairman; J. W. Simons, vice-chairman, and W. E. Hudson, secretary-treasurer. It was suggested in the business session that a stag meeting be held in South Georgia some time during the next year and include a deep-sea fishing trip. Announcement was made of the next Southern Section meeting, to be held at Birmingham, Ala., February 7 to 9, 1940.

Entertainment included a party for the ladies, at the home of Mrs. Driftmier, a picnic lunch near the shoals on the Southern Piedmont Experiment Station near Watkinsville, an inspection tour of that station, a baseball game between Florida and Georgia, an informal supper at Wickersham Lodge, near Athens, and a dance sponsored by the Georgia Student Branch of the A.S.A.E.

ASAE Meetings Calendar

June 19-22, 1939—Annual meeting, University Farm, St. Paul, Minn.

July 25, 1939—Pacific Coast Section, Treasure Island, San Francisco, Calif.

September 12-14, 1939—North Atlantic Section, Farmingdale, Long Island, New York.

Five Past Presidents Attend Chemurgic Meet

FIVE past presidents of the A.S.A.E. attended the Mid-American Farm Chemurgic Conference at Columbus, Ohio, May 19 and 20. They were Arthur Huntington, L. F. Livingston, G. W. McCuen, F. A. Wirt, and Arnold Yerkes. Mr. Livingston was on the program and Mr. Yerkes is a director of the National Farm Chemurgic Council.

Wheeler McMillen (Assoc. A.S.A.E.), president of the National Farm Chemurgic Council, was general chairman of the conference.

Other A.S.A.E. members noted in the audience during all or part of the conference included I. P. Blauser, B. Gwynne Burr, A. H. Glaves, W. H. Lloyd, Virgil Overholt, C. O. Reed, and E. A. Silver.

In addressing the Conference, Mr. Livingston made a plea for increased investment in agricultural research.

Roadside Development Awards

SECTIONAL and national roadside development awards have been announced by "Contractors and Engineers Monthly" for excellence of execution of roadside development projects and for suggestions as to methods of achieving better results or greater economies on such projects. Awards will be made annually and will be based on considerations including water and soil erosion control affecting lands adjacent to the highways. The publication believes that conditions of the competition will stimulate increased interest in erosion prevention on the part of state highway departments and contractors.

(News continued on page 242)

"CATERPILLAR" DIESELS ON THE CONSERVATION PROGRAM!

● The 60-inch gauge "Caterpillar" Diesel D4 Tractor teamed with the No. 22 Terracer provides T. B. Studer, Hemphill County, Texas, a balanced outfit. Note how positive traction and accurate steering even on the loose terrace ridge assure plenty of power to roll up a full blade of soil every trip!

● An outfit of Butler Brothers, Terracing Contractors of Oklahoma City. The Diesel D6 with bulldozer quickly builds up low spots in the ridge. Each of their Diesel D6 tractors, operating a No. 2 Terracer, commonly builds a mile of wide-base terrace per 10 hours, on only 25 gallons of low-cost fuel!

● W. B. Wilson, Custer County, Oklahoma, employs a Killefer Revolving Scraper with his Diesel D4 tractor—building Range Program dams on contract. Moving 240 cubic yards per 8 hours on 72c worth of fuel. Plenty of power to load the scraper in hard soil—plenty of traction to climb the fill!

● To conserve water and resist soil-blowing, O. H. Finch, Dallam County, Texas, lists this hummocky, sandy field—35 acres in 10 hours with his Diesel D2, on less than 13 gallons of fuel! This tractor pulls steadily at 3.6 M.P.H. even on loose, uneven footing.

● Besides the jobs shown, "Caterpillar" Diesel Tractors are at work on pasture contouring, noxious weed control, ditching, filling gullies, cutting-in cover crops—proving their special fitness for conserving soil, moisture and cash on all varieties and sizes of projects! Your request for further facts will receive the prompt attention of "Caterpillar" Agricultural Engineers.

CATERPILLAR

TRACTOR CO. PEORIA, ILLINOIS

DIESEL ENGINES TRACK-TYPE TRACTORS TERRACERS

Iowa Wins F.E.I. Student Branch Cup

WINNER of the annual F.E.I. Student Branch Cup Award for the school year of 1938-39 is the Student Branch of A.S.A.E. at Iowa State College, according to announcement of the awarding committee. The Branch at Oregon State Agricultural College was granted second place recognition, and the Branch at Ohio State University, third.

The award, established by the Farm Equipment Institute, is made annually to the A.S.A.E. Student Branch rated highest for the year in quality, extent, success, and balance of extra-curricular activities initiated, carried on, or participated in by it and its individual members, as evidenced by a report submitted for judgment in the competition.

This year's A.S.A.E. committee on the F.E.I. Award included Frank J. Zink, chairman, J. W. Carpenter, and O. W. Sjogren. The Iowa students documented their activity for the school year with a bound volume of more than one hundred typewritten pages, and a similarly bound supplement of thirty pages covering its Field Day, May 12, held after the closing date for submission of regular reports in the competition. Both the original report and the supplement included illustrations and exhibits.

Twelve student branches entered the competition for the award this year.

Washington News Letter

FROM AMERICAN ENGINEERING COUNCIL

CIVIL SERVICE SEEKS ADVICE FROM PROFESSION

THE President's Committee on Civil Service Improvement has authorized the appointment of a number of special advisory committees and Gano Dunn, a member of the President's Committee, with the assistance of officers of the National Academy of Sciences, the National Research Council and others, the American Engineering Council, the American Society of Civil Engineers and other leading engineering and technical societies, has appointed three such committees of five members each—one, covering the fields of mathematical, physical, and biological sciences, called for short, the Science Committee; a second, covering the fields of the general engineering societies consisting of the American Society of Civil Engineers, the American Institute of Mining and Metallurgical Engineers, the American Society of Mechanical Engineers, the American Institute of Electrical Engineers, the Institute of Radio Engineers, which is known as the General Engineering Committee; and a third committee covering the fields of the specialized engineering societies, consisting in part of the American Society of Heating and Ventilating Engineers, the Society of Automotive Engineers, the American Society of Agricultural Engineers, the Illuminating Engineering Society, the American Society of Refrigerating Engineers and representatives of local and state engineering societies, to be known as the Specialized Engineering Committee.

The memberships in these committees have been selected with reference to qualifications for formulating valuable opinion on civil service matters either through present or past employment in the government service, experience with merit systems in private industrial or educational fields or demonstrated personal interest in and knowledge of the history and present problems of the Civil Service. (S. P. Lyle represents the A.S.A.E. and agricultural engineering field on the specialized engineering committee.)

COUNCIL AIDS MAPPING

To aid the Federal Board of Surveys and Maps in obtaining a true picture of the needs for such aids to engineering John S. Dodds, AEC representative on the Board's advisory council requested all of the 54 member organizations of AEC to submit their views on the question. Replies are still coming in and are providing valuable assistance to the Federal Board, particularly in indicating areas where mapping is most urgent.

Personals

C. L. Hamilton is author of "Terracing for Soil and Water Conservation," published as Farmers' Bulletin No. 1789 of the U. S. Department of Agriculture, superseding its Farmers' Bulletin No. 1669.

R. B. Hickok is now stationed at Purdue University as acting project supervisor of watershed and hydrologic studies to be conducted cooperatively by the Indiana Agricultural Experiment Station and the U. S. Soil Conservation Service. He is located in the New Agricultural Engineering Building, Purdue University, Lafayette, Indiana.

A. C. Jacquot has written Popular Bulletin No. 156 of the State College of Washington, entitled "Diesel Tractor Engines."

H. F. McColly, beginning July 1, will be on a year's leave of absence from his duties as head of the agricultural engineering department of North Dakota Agricultural College, and during that period will serve as secretary and chief engineer of the State Water Conservation Commission, with headquarters at 1301 State Capitol, Bismarck, N. Dak.

R. W. Trullinger is author of the agricultural engineering section of the "Report on the Agricultural Experiment Stations, 1938," which section is also reprinted as a separate pamphlet.

Applicants for Membership

The following is a list of applicants for membership in the American Society of Agricultural Engineers received since the publication of the May issue of AGRICULTURAL ENGINEERING. Members of the Society are urged to send information relative to applicants for consideration of the Council prior to election.

Walter L. Abney, junior agricultural engineer, Soil Conservation Service, U. S. Department of Agriculture. (Mail) Box 197, Carnesville, Ga.

Brooke Anderson, Inland Steel Company, 38 S. Dearborn St., Chicago, Ill.

J. Clyde Bowles, junior erosion engineer, Tennessee Valley Authority, Wilson Dam, Ala. (Mail) Box 1222.

Earl L. Bradshaw, assistant engineer, Soil Conservation Service, U. S. Department of Agriculture. (Mail) Box D, McLean, Tex.

G. N. Britt, junior soil erosion engineer, Tennessee Valley Authority. (Mail) Box 607, Pulaski, Tenn.

Elwin DeWitt Butler, research fellow, agricultural engineering department, Iowa State College, Ames, Iowa.

H. F. Carroll, buyer in farm equipment division, Montgomery Ward and Company. (Mail) 1027 Hayes Ave., Oak Park, Ill.

Joseph P. Ditchman, illuminating engineer, General Electric Company, Nela Park, Cleveland, Ohio.

Charles Louis Gouffon, junior erosion engineer, TVA Forestry Department, Parisian Building, Paris, Tenn.

Thomas E. Griffin, junior agricultural engineer, Soil Conservation Service, U. S. Department of Agriculture. (Mail) SCS-21-N, Mountainair, N. M.

Dayton E. Hazzard, junior agricultural engineer, Soil Conservation Service, U. S. Department of Agriculture. (Mail) McIntosh, S. D.

James G. Henry, junior agricultural engineer, Soil Conservation Service, U. S. Department of Agriculture. (Mail) Camp SCS-3, Dyer, Tenn.

James H. Howlett, assistant agricultural engineer, Soil Conservation Service, U. S. Department of Agriculture. (Mail) Camp SCS-3, Dyer, Tenn.

William F. Long, junior agricultural engineer, Soil Conservation Service, U. S. Department of Agriculture. (Mail) 306 1st Ave., N., Great Falls, Mont.

Howard D. McMurtry, assistant engineer, Soil Conservation Service, U. S. Department of Agriculture. (Mail) 1703 L. St., Bedford, Ind.

William R. Oglesbee, assistant RR supervisor, Farm Security Administration, Swainsboro, Ga.

Wesley E. Patton, Jr., assistant district engineer, TVA Forestry Relations Department. (Mail) 555 Oak View Circle, Florence, Ala.

Bruce M. Perry, junior erosion engineer, TVA Forestry Relations Department, 305 Times Building, Huntsville, Ala.

Clark Prudhon, agricultural bureau, market development division, American Rolling Mill Co., Middletown, Ohio.

Cecil M. Salley, junior agricultural engineer, Soil Conservation Service, U. S. Department of Agriculture. (Mail) Box 150, Heber Springs, Ark.

Dean Searls, rural representative, Illinois Iowa Power Co., Decatur, Ill. (Mail) 1298 W. Decatur St.

Leon F. Silberberger, assistant agricultural engineer, Soil Conservation Service, U. S. Department of Agriculture. (Mail) Beverly, W. Va.

J. L. Thompson, agricultural engineer, Dominion Experimental Farm. (Mail) Vol Marie, Saskatchewan, Canada.

D. R. Vallicott, area engineer, Soil Conservation Service, U. S. Department of Agriculture. (Mail) 1326 N. 38 St., Lincoln, Nebr.

C. B. Wilder, assistant agricultural engineer, Soil Conservation Service, U. S. Department of Agriculture. (Mail) Box 233, Hawkinsville, Ga.

A. J. Wojta, assistant agricultural engineer, Soil Conservation Service, U. S. Department of Agriculture. (Mail) Box 146, Highland, Wis.

Ray R. Wood, junior agricultural engineer, Soil Conservation Service, U. S. Department of Agriculture. (Mail) Box 1151, Gallup, N. M.

"Well, Mr. Jones, here's what I think about Fence:

"IN the first place, good fence is absolutely necessary if you practice balanced farming, including soil conservation, livestock and livestock sanitation.

"But you must realize, of course, that all fence is not equally effective. There are many points to consider in choosing good woven-wire fence.

"What's that? Oh yes—well American seems to be the best known and most widely used, and it has certainly stood the test of time.

"Yes—it's made by responsible people—American Steel & Wire Company and other Subsidiaries of United States Steel Corporation.

"Yes, Mr. Jones, I can tell you the principal features of American Fence. It is strong and springy. It is heavily and properly galvanized to withstand corrosion — and made of copper-bearing U·S·S Long-life, rust-resisting wire.

"I beg your pardon? Oh yes—the stay wires are properly placed, the wraps are long and tight, the wire is full gage.

"You can feel perfectly sure of getting full length, full weight rolls and real value when you buy American Fence. I'm sure you'll be satisfied.

"I have often recommended American Fence and I've never had any reason to regret it."

Write today for a free copy of our book "Wire and Steel Products for the Farm." Tells what points to consider in choosing fence, posts and gates. How to erect fence properly. Interesting facts on other wire products for the farm, too. Send for it today.

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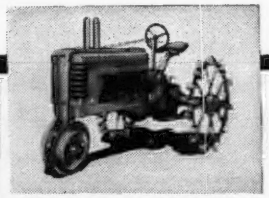
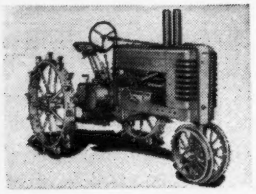
Two-Cylinder Economy—
FOR *EVERY FARM*

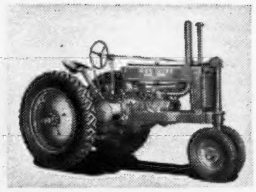
THE NEW JOHN DEERE MODEL "H"



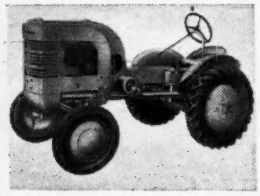
Model "B"—Pulls two 14-inch plow bottoms in average soil conditions; daily work output of six to eight horses.



Model "A"—a heavy-duty 2-plow tractor for larger farms. Pulls two 16-inch plow bottoms in average soil conditions.



Model "G"—a powerful 3-plow tractor for the large row-crop farms. Handles big-capacity four-row equipment.



Model "L"—a 1-plow tractor for small farms; available with a complete line of one-row equipment.

NOW, every farmer can enjoy the time-, labor-, and money-saving advantages of owning a John Deere *Two-Cylinder* General Purpose Tractor. The addition of the new Model "H" rounds out the most complete, most modern line of wheel-type tractors—there's one for every farm . . . for every crop . . . for every purpose . . . *for every pocketbook.*

The smaller, lower-priced John Deere Model "H" is making tractor history in its amazing economy . . . in its greater work output . . . in its ability to replace animal power . . . in its all-around performance on all farm jobs.

This sensational new tractor meets the demands of small-acreage farmers everywhere for a tractor they can afford to own—a tractor that handles *all* of their power jobs. It meets the demands of large-acreage farmers who have always wanted and needed economical auxiliary power to handle their lighter farm jobs.

Powered with the same type of two-cylinder, distillate-burning engine and offering the same practical advantages that have made the larger John Deere General Purpose Tractors famous, the new Model "H" handles every job within its power range faster, easier, better, and at new low costs—far lower costs than with animal power. See your John Deere dealer; fill out coupon for full information.

Cultivates two rows. Fits all crops. Pulls a two-bottom, 12-inch plow under favorable conditions. Belt pulley standard equipment; power take-off available. Handles horse-drawn tools; available with a complete line of low-cost drawn, integral, belt- and power-driven machines.

and REMEMBER—

—the integral equipment for your tractor is as important as the tractor itself. Don't overlook the faster, better work, the easier handling, and the longer life of the complete line of John Deere Integral Equipment—equipment that's built to match the greater value you get in a John Deere General Purpose Tractor.

for more information

John Deere, Moline, Ill.
Dept.

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Model "H" ☐ Model "B" ☐
Model "A" ☐ Model "G" ☐
Model "L" ☐

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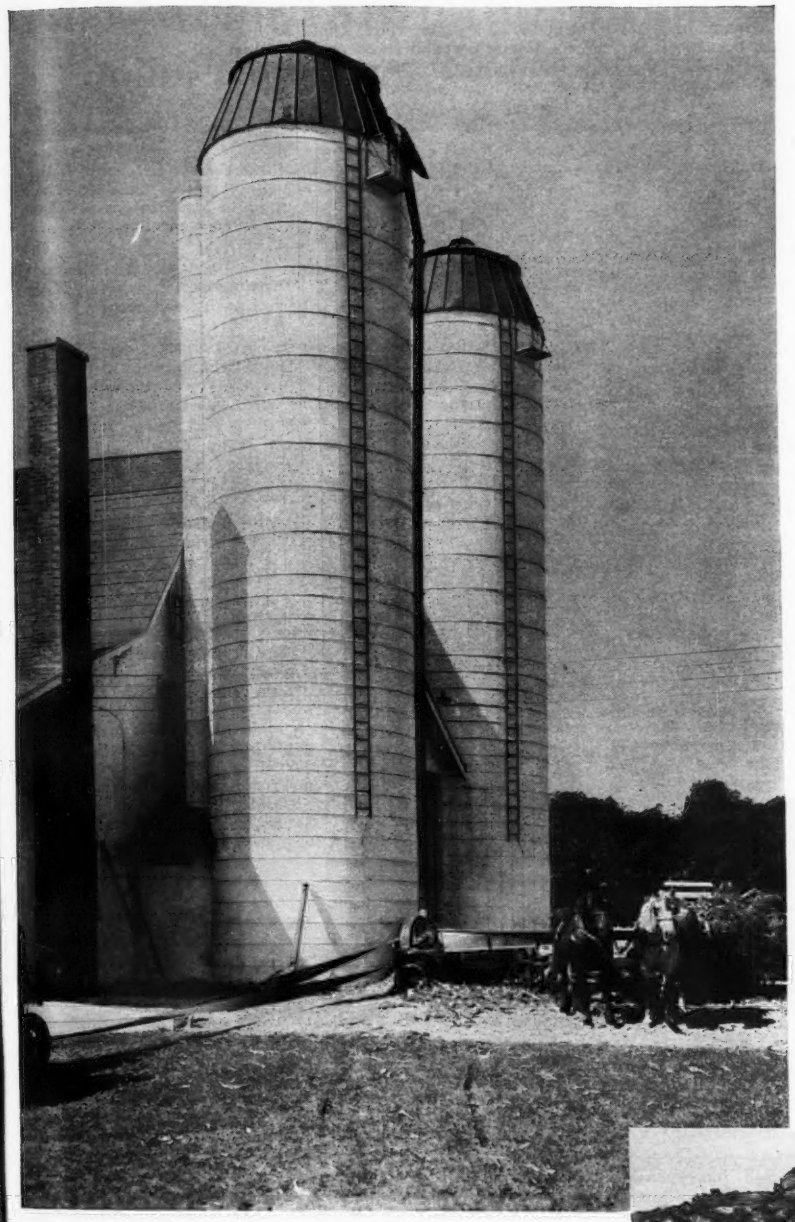
...but Dynamite came FIRST!



YOU accept as a matter of course the modern building materials and methods that make your concrete farm buildings economically possible. You take for granted the economy and operating efficiency of your modern farm machinery that helps you lower your production costs.

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Without dynamite, you'd have *none* of these 20th Century improvements. Dynamite quarries the rock for the millions of tons of cement used every year. Dynamite blasts the ore needed for the vital metals used to make your farm machinery, implements and the equipment in your buildings.

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But more than that, dynamite proves its economy right on the farm. So much so, that more and more farmers and farm leaders are using more and more dynamite every year. They've found it saves work and saves money.

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Concrete farm buildings start *here*, where dynamite quarries the rock for cement. Dynamite also mines the metals used in farm machinery, rural electrification, the very car you drive. Remember: *Dynamite* came FIRST!

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EXPLOSIVES DEPT.

WILMINGTON, DELAWARE

Agricultural Engineering Digest

A review of current literature by R. W. TRULLINGER, assistant chief, Office of Experiment Stations, U. S. Department of Agriculture. Copies of publications reviewed may be procured only from the publishers thereof, whose names and addresses may be obtained on request to AGRICULTURAL ENGINEERING, St. Joseph, Michigan

SOIL INVESTIGATIONS AT THE PUERTO RICO STATION. Puerto Rico Sta. Rpt. 1937, pp. 6-16, 105-109, figs. 11. Work on erosion and its control is taken up under the following captions: Erosion has been proceeding rapidly from a geological viewpoint, unprotected hillside cornfields have lost best topsoils by erosion, hillside cultivation of tobacco has been wasteful of fertile topsoils, regional planning could avoid wasteful crops on steep hillsides, annual crops needing frequent tillage have increased erosion on steep hillsides, severe erosion has followed root crops on steep hillsides, broad bench terraces have been used for winter vegetable crops on steep hillsides, high-value crops were necessary to yield return on increased investment in terraced land, as density of population increases greater expenditures are reasonable for productive land, narrow, canalled terraces were constructed more cheaply than broad benches, mangum terraces are less expensive than bench terraces, different methods of planting the areas between mangum terraces have been tried, contour canals lessened erosion in hillside bush and small-tree crops, crop selection for hillside plantings can minimize erosion, and earth dams for flood control have reclaimed land.

THE CAPACITY OF FLATTENED TUBE JUICE PASTEURIZERS *J. L. Heid* and *W. C. Scott*. (U. S. D. A.). Fruit Prod. Jour. and Amer. Vinegar Indus., 16 (1937), No. 5, pp. 136-139, figs. 3. Performance data on straight and coiled tubular juice pasteurizers are given, together with calculations of capacity, juice velocity, thermal efficiency, and heat exchange rate. The heat exchange rate was appreciably higher in the coiled tube.

AGGREGATION OF SOILS AND CALCIUM ION SATURATION *L. D. Baver*. (Univ. Mo.). Amer. Soil Survey Assoc. Bul. 17 (1936), pp. 28-30. The calcium ion may influence granulation directly by causing a flocculation of particles which may be bound together into stable aggregates, as by organic matter. Therefore, the present amount of exchangeable calcium in the soil would not be an indication of the stability of soil granulation. Calcium may influence granulation indirectly through its effect upon organic matter. It helps to preserve organic matter in the soil. It is concluded that calcium ions have important effects on soil granulation, but most of those observed are probably indirect rather than direct.

THE VALUE AND LIMITATIONS OF CALCIUM IN SOIL STRUCTURE, *R. Bradfield*. (Ohio State Univ.). Amer. Soil Survey Assoc. Bul. 17 (1936), pp. 31, 32. The author cites two examples of soils containing both organic matter and calcium carbonate in percentages apparently quite sufficient for good structure, both soils being in practice unproductive and of very poor structure. These instances are thought to indicate "that while lime and organic matter may favor the development of a favorable structure in heavy soils, they do not in themselves insure a good granular structure. The best structure is usually found in virgin soils or in soils that have been in sod for several years."

FACTORS AFFECTING DOWNWARD MOVEMENT OF WATER IN SOILS, *G. B. Bodman*. (Univ. Calif.). Amer. Soil Survey Assoc. Bul. 17 (1936), pp. 33-38, figs. 5. The author considers briefly three types of movement: (1) Movement through soils saturated throughout, (2) movement through soils unsaturated throughout, and (3) entry of water into columns from a region of complete saturation to one of unsaturation. Downward movement of soil water as determined by laboratory measurement through columns of disturbed soil packed into tubes and by field experiments with undisturbed, deep soil columns *in situ*, and the effects of texture, apparent density, temperature, and water content of the soil upon such movement are discussed.

EFFICIENCY OF THE MOISTURE SUPPLY, *R. Deland* and *T. J. Dunnewald*. (Univ. Wyo.). Amer. Soil Survey Assoc. Bul. 17 (1936), pp. 39, 40. Loss of moisture by evaporation during the natural melting of snow and ice was shown. Experiments in which plants were grown in soils from which evaporation was prevented by covering the surface with petroleum jelly, the experiment being continued until permanent wilting took place and the moisture content of the soil then determined, were also carried out. A light fine sandy loam had retained but 5 per cent of moisture at permanent wilting, whereas a heavier soil, of loam texture, held from 13 to 15 per cent of moisture when the test plants wilted.

COMMITTEE ON NOMENCLATURE, SUB-COMMITTEE ON EROSION TERMS, *J. M. Snyder* and *A. H. Paschall*. Amer. Soil Survey Assoc. Bul. 17 (1936), pp. 96, 97. The authors list and define 35 terms.

NOMENCLATURE COMMITTEE OF THE INTERNATIONAL SOCIETY OF SOIL SCIENCE, *C. F. Shaw*. (Univ. Calif.). Amer. Soil Survey Assoc. Bul. 17 (1936), pp. 98, 99. This is a committee report mainly concerned with definitions noted above.

CONSERVATION OF THE ORGANIC SOILS IN THE SACRAMENTO-SAN JOAQUIN DELTA, *S. W. Cosby*. (U. S. D. A.). Amer. Soil Survey Assoc. Bul. 17 (1936), pp. 116, 117. Dangers of injury to the valuable organic soils here discussed include failure of the protective levees, accumulation of salts and alkalinity, and fire. The last named danger is stressed as the most serious. Both intentional burning-over and spectacular uncontrolled conflagrations occur. Even controlled "light" burning is shown to be a very destructive practice.

A STUDY OF ROOT DISTRIBUTION IN PRAIRIE CLAYPAN AND ASSOCIATED FRIABLE SOILS, *E. G. Fitzpatrick* and *L. E. Rose*. (U. S. D. A. and Okla. Expt. Sta.). Amer. Soil Survey Assoc. Bul. 17 (1936), pp. 136-145, figs. 7. Most of the roots were found to occur in the topmost 30 in in each type of soil. A few roots reached a depth of 54 in. A fairly high concentration of roots was found in the topmost 3 in, with a slightly lower concentration at a depth of 6 in in each soil. An increase in the concentration of roots was found in heavier textured horizons, this increase being greatest in clay pans. Roots penetrated throughout the clay pan rather than following around the outsides of clay pan columns. A marked decrease in root concentration was found in gray layers and incipient gray layers lying immediately above clay pans. Poor drainage of this horizon may, it is believed, explain this condition.

THE BROADER ASPECTS OF SOIL CONSERVATION, *M. F. Miller*. (Univ. Mo.). Amer. Soil Survey Assoc. Bul. 17 (1936), pp. 146-149. This is a general summary of the problem of the preservation of our soils and of their productivity.

SOME REMARKS ON THE SCOPE AND CHARACTER OF RESEARCH IN SOIL AND WATER CONSERVATION, *R. V. Allison*. (U.S.D.A.). Amer. Soil Survey Assoc. Bul. 17 (1936), pp. 150-154. The author briefly outlines a program of which the five principal groups of projects are climatic and physiographic studies, soil and water conservation investigations, watershed and hydrologic studies, sedimentation and hydraulic studies, and economics of soil erosion control.

SOIL EROSION CONTROL, *A. E. Burges*. Atlanta, Ga.; Turner E. Smith & Co., 1937, rev. ed., pp. XVII+221, [figs. 73]. The author expresses the opinion that although much has been written concerning soil erosion, this material has usually been contributed "by those only superficially acquainted with the subject or by specialists unable to see the subject as a whole. . . . Not until now has there been available to the public any book in which this bewildering mass of data has been reduced to its essentials. This volume presents erosion control as an organized whole—a new science borrowing freely from soils, agronomy, forestry, animal husbandry, and engineering, yet being none of these. As it is developed here, soil erosion control embraces every phase of farm management which has a bearing on the preservation of the soil."

The station also reports experiments, by J. O. Carrero, indicating that the applications of sulfur needed to prevent chlorosis of sugarcane on highly alkaline, calcareous soils are too large to be economically feasible, although lowered pH value and increased permeability were brought about. *(Continued on page 250)*

Better Roads

Go Right Down the Middle

(*In this case the middle of a swamp*) *with* ATLAS Fill Settlement Methods

Highway construction between Kissimmee and Haines City, Florida.

Preparing the blast. Note unique loading device at left.

After one shot. Fill has settled.

"Fill settlement" with Atlas Explosives makes possible many a permanent road, over swampy territory.

For a long time, swamps presented a tough problem in highway construction. Roads had to be "floated" across or "take to the hills." Wavy or winding roads over higher cost right-of-way resulted.

The problem was solved by using explosives to settle the highway fill. In this development, as in so many others involving explosives, Atlas methods and Atlas Explosives have made outstanding contributions.

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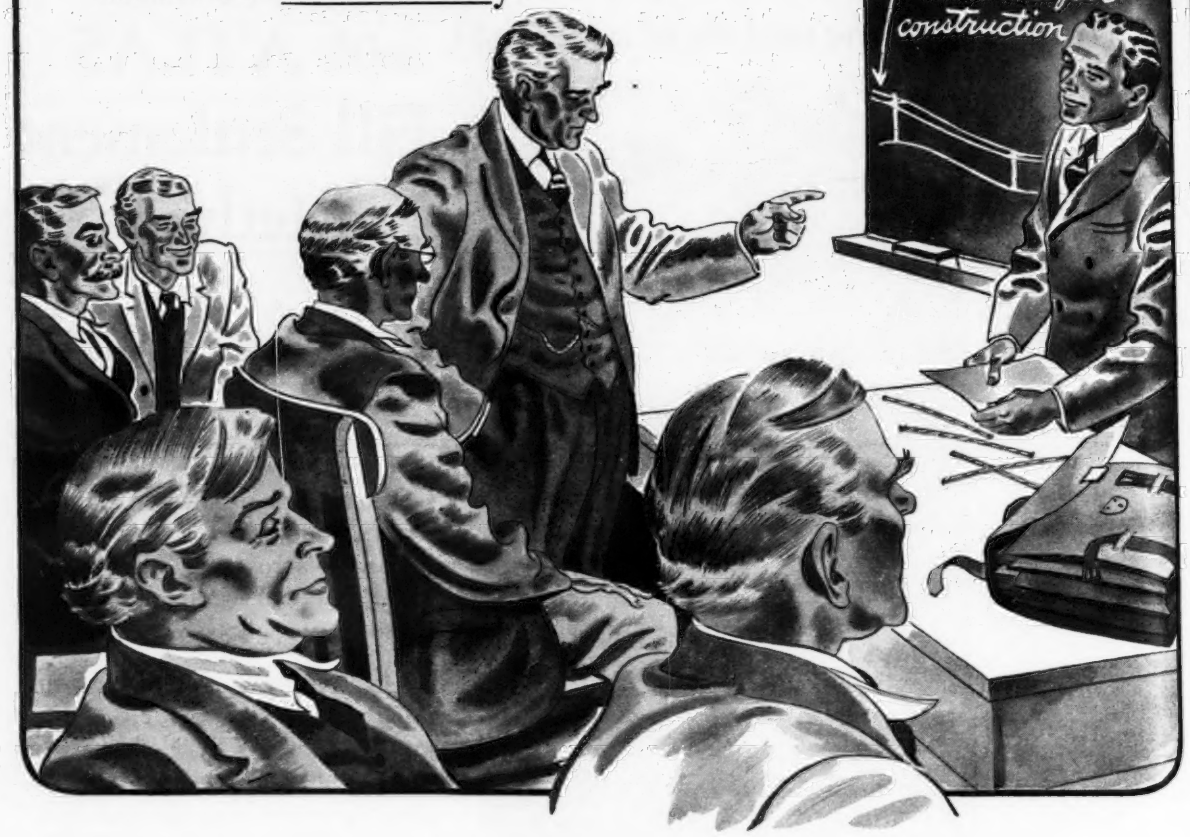
CHEMICALS ATLAS EXPLOSIVES

"Brother, a power line must deliver electricity!"



"Stay up, of course. But I'm seeing to it that every farm on this line gets plenty of electricity."

Right you are, Mr. Farm Board Member, in insisting on A.C.S.R. conductors. In addition to high strength, they'll give your rural main and tap lines plenty of conductivity. And your appliance selling program can go ahead without fear of bogging down, backed by lines that will supply power at ample voltage.

A.C.S.R. provides the high strength and resistance to corrosion that give lines long life, dependability and freedom from maintenance expense. Long span construction is employed with safety. ALUMINUM COMPANY OF AMERICA, 2195 Gulf Building, Pittsburgh, Pennsylvania.

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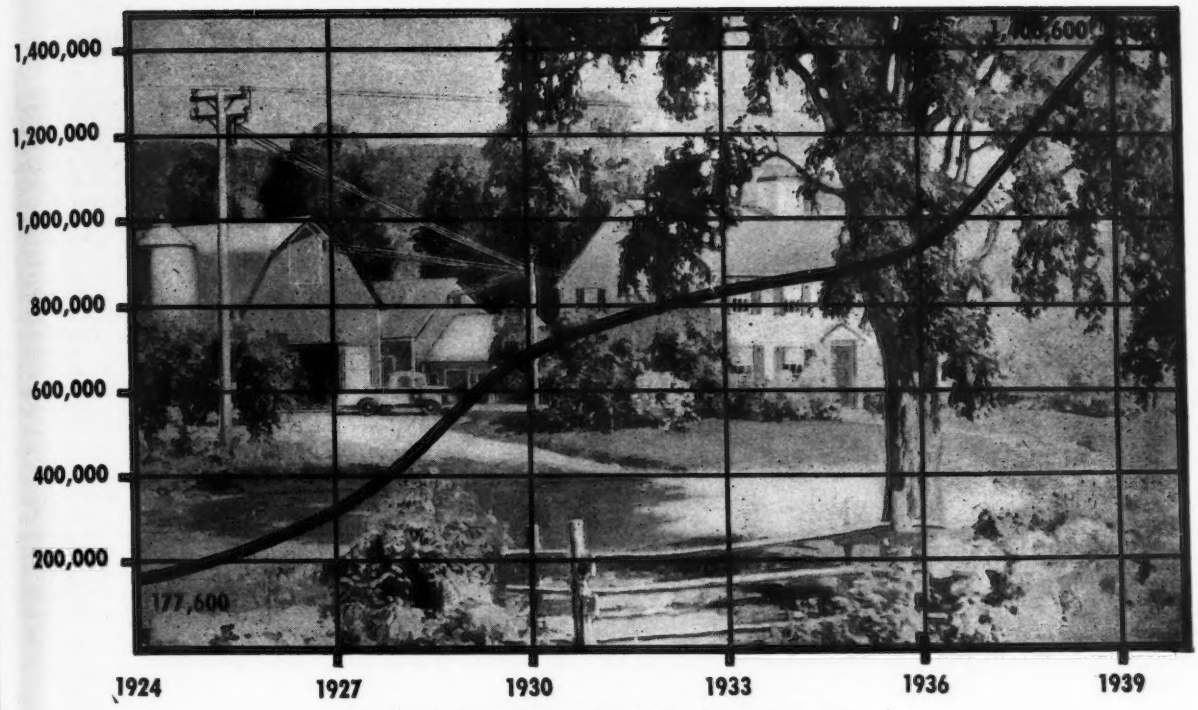


Farms in U. S. receiving electric service from power lines

MORE POWER TO MORE FARMERS

TO THE American Society of Agricultural Engineers—congratulations on your 33d year of continuous service to American agriculture.

In its first third of a century, A.S.A.E. has done much to increase the profits and pleasures that have been derived from farming in America.

For example, in your lifetime it has helped raise farm electrification from its infancy to an industry which now serves more than 1,400,000 farm homes. You have assisted in giving the farmer the greatest source of power he or his predecessors have ever known. You have discovered more than 200 ways in which the farm family can use this power on the farm and in the home.

By showing these farm families how to obtain greater profits through a wider use of electric service, you have made possible the extension of electric lines to many farmers who otherwise would have remained beyond the reach of electricity. Truly, you have helped provide more power to more farmers—at less cost.

The 33d anniversary of A.S.A.E. is a fitting time to look back—but an even more fitting time to think and plan progress for the years to come. New developments forecast years of sound growth. The success of farm electrification in the future lies in the hands of the agricultural engineers, who have so ably brought it to the prominent position it has today.

NEW YORK WORLD'S FAIR—SEE THE G-E "HOUSE OF MAGIC"—SAN FRANCISCO EXPOSITION

GENERAL ELECTRIC

98-39

An Opportunity *for* LEADERSHIP

Agricultural engineers have accepted the responsibility of leadership in the design of farm structures.

But leadership cannot rest. Today, the engineer no longer designs solely for "use requirements." He looks beyond to the vital factors of economy, permanence and, most of all, *firesafety!*

There is no hope of altering the conditions of isolation and the general absence of fire-fighting equipment which make these farm fires tragic. The certain remedy is to *design with firesafe materials!*

Concrete won't burn! It can't be ignited by flying sparks or embers; resists the spread of fire from adjacent buildings; confines fire to the structure in which it originates. Yet concrete construction is available in every locality . . . compares favorably in cost with any other permanent construction . . . offers lowest upkeep through decades of satisfactory service.

For every farm building there is a concrete design which will provide a good-looking, well-insulated structure at low cost. Our agricultural engineers will gladly confer with you on design questions involving the use of concrete.

PORTLAND CEMENT ASSOCIATION

Dept. A6-1, 33 W. Grand Ave., Chicago, Ill.

A National Organization to Improve and Extend the Uses of Concrete

FIRESAFE CONSTRUCTION IS THE BEST FIRE PROTECTION

Agricultural Engineering Digest

(Continued from page 246)

THE EFFECT OF VEGETATION UPON SNOW COVER AND FROST PENETRATION DURING THE MARCH 1936 FLOODS, *C. H. Diebold.* (Cornell Univ.). Jour. Forestry, 36 (1938), No. 11, pp. 1131-1137, figs. 2. Although the value of forests for flood control has long been debated, relatively few studies of the subject have been made. The 1936 floods occurred while the author was making intensive studies on the effect of vegetation upon snow cover and soil temperature in the 1,880-acre Arnot Forest near Ithaca, N. Y., and the data accumulated indicate that hardwood forests are a favorable influence which should be considered in flood control programs. The acreage of frozen soil and floods was confined principally to bare, exposed fields possessing a scanty snow cover during the winter. The soil was frozen neither at 12 hardwood forest stations nor at 6 stations with herbaceous cover. Hardwood forests, as compared with bare fields and herbaceous cover, greatly reduced the drifting of snow, thus favoring a deep, well-distributed snow cover. Reforestation of areas where the snow cover is irregular and the soils freeze deeply and the protection of forest lands should reduce the acreage of frozen soils and increase the snow retention, thereby reducing the peaks of floods.

THE SIGNIFICANCE OF FIELD STRUCTURE IN THE WATER RELATIONS OF SOILS, *G. W. Musgrave.* (U. S. D. A.). Amer. Soil Survey Assoc. Bul. 17 (1936), pp. 155-162, figs. 2. Modifications of the structure of the soil in the surface 6 in were manifested in the movement of water to a depth of at least as great as 3 ft in two very different soils. The addition of organic matter increased water intake, reduced surface runoff, and greatly improved water relations within the entire soil profile.

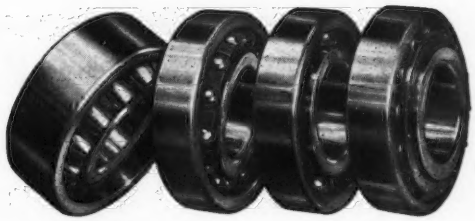
THE ROLE OF STRIP-CROPPING IN EROSION CONTROL IN THE BLACKLANDS OF TEXAS, *E. B. Deeter.* (Tex. Expt. Sta.). Amer. Soil Survey Assoc. Bul. 17 (1936), pp. 163, 164. The author reports experiments in which erosion was markedly reduced by alternate strip cropping of oats with cotton as compared either with cotton grown in rows down the slope or cotton alone on the contour. He further expresses the opinion that where terracing is also needed but cannot be done at once, strip cropping "will usually afford an excellent degree of protection until it is found possible to terrace the land."

A DIRECT METHOD OF AGGREGATE-ANALYSIS OF SOILS AND A STUDY OF THE PHYSICAL NATURE OF EROSION LOSSES, *R. E. Yoder.* (Ala. Expt. Sta.). Amer. Soil Survey Assoc. Bul. 17 (1936), p. 165. The method consists essentially in allowing a given quantity of air-dry soil to slake through a graded nest of screens immersed in a constant volume of water. The nests of screens are mechanically raised and lowered at a slow rate for a constant time interval to facilitate separation of the various sized aggregates.

Literature Received

S.A.E. HANDBOOK, 1939 edition. XXXVII+776 pages ("skip" system of page numbering) 5¾x8½ in., cloth bound. Revised, up-to-date information on the standards policy, standards, new and revised standards, organization and procedure. Standards published are grouped by subject matter as follows: Units, Parts and Fittings; Materials, Processed; Materials Fabricated; Screws, Bolts and Washers; Tests, Ratings, and Codes; Transportation and Maintenance; Tools and Production Equipment; Nomenclature and Definitions; and Miscellaneous Specifications. Additional information includes Standards Committee Regulations, and American Standards, a list of automotive standards promulgated by the American Standards Association. Society of Automotive Engineers, Inc., New York City. Price to non-members of S.A.E., $5.00.

AGRICULTURAL ENGINEERING IN NORTH AMERICA AND GERMANY, by C. Culpin. XII+162 pages, 7½x10 in., cloth bound. Published by the College of Estate Management, London, as No. 6 in a series of reports of the college travelling scholars in agriculture. Chapter headings include Summary and Reflections; The Scope and Accomplishments of Agricultural Engineering in the United States and Germany; The Organization of the Research and Educational Services in Agricultural Engineering in the United States; The Organization of the Research and Educational Services in Agricultural Engineering in Germany; Research and Recent Developments in Agricultural Engineering in the United States; and Research and Recent Developments in Agricultural Engineering in Germany. An appendix lists institutions visited by the author. Indexed. Printed for private circulation, no price stated. Report No. 5 in the same series covers "Observations on American Dairy Husbandry," by Arthur S. Foot.



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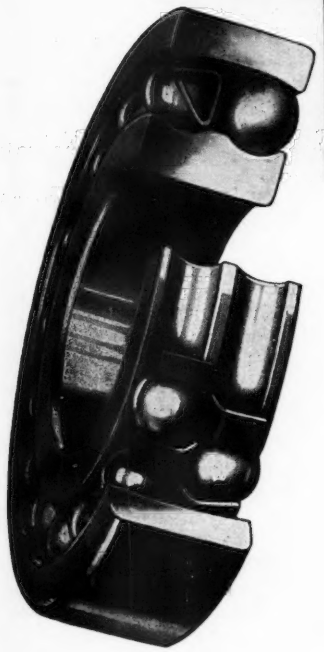

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Supplementary Irrigation

(Continued from page 237)

covering a distance of 300 ft on each side. This system consisted of canals 600 ft apart connected by cross canals. The pump and nozzles were mounted on a small boat. Each of two nozzles was covering half the distance to the next canal. The boat was propelled by directing the jet at a slight angle to the direction of the canal.

Where conditions were carefully selected subsurface irrigation has given excellent results in Ohio. In the Scioto Marsh it has been common practice to pump water from the river back through the regular tile drainage system. The soil is muck underlaid with an impervious clay. The tile lines are frequently spaced more than 100 feet apart. Some of the swamp lands east of Toledo depend upon pump drainage. During dry weather water is pumped back from the lake into the drainage system with excellent results. A 16-acre drainage-irrigation system is now being installed on the Cooley farms owned by the City of Cleveland, and a 7-acre system on the Gallipolis state farm.

Some farmers have demanded a simple method of measuring the quantity of water applied. Since the water is carried in closed pipes, it cannot be measured by the Parshall flume used so widely throughout the West. The Venturi meter, shown in the accompanying sketch, is a simple method of measuring this flow of water.

This meter is suitable only where there is a stationary pumping plant. It is made of reinforced concrete with a brass throat. A glass mercury gage registers the difference in pressure head between the line and the throat. This gage is graduated to read directly in gallons per minute. It carefully made it will have an error, even without calibration, not exceeding 1.5 per cent.

The discharge is calculated from the following equation:

$$Q = CA_t = \sqrt{\frac{2gh}{1 - \frac{(A_t)^2}{(A_p)}}}$$

Where A_p is the area at the inlet, A_t is the area at the throat, and h is the difference in pressure heads at A_p and A_t. The coefficient C will vary from 0.97 to 0.99.

The meter is of course not provided with any recording device but the discharge at any instant is easily read. It is designed to be installed in a 6-in line and is intended to register discharges up to 500 gal per min.

EMPLOYMENT BULLETIN

The American Society of Agricultural Engineers conducts an employment service especially for the benefit of its members. Only Society members in good standing may insert notices under "Positions Wanted," or apply for positions under "Positions Open." Both non-members and members seeking to fill positions, for which ASAE members are qualified, are privileged to insert notices under "Positions Open," and to be referred to members listed under "Positions Wanted." Any notice in this bulletin will be inserted once and will thereafter be discontinued, unless additional insertions are requested. There is no charge for notices published in this bulletin. Requests for insertions should be addressed to ASAE, St. Joseph, Michigan.

POSITIONS WANTED

AGRICULTURAL ENGINEER with bachelor's degree from Texas A & M College, master's degree in farm structures from Iowa State College, two years' teaching experience in college, and a year's research experience desires a position in a southern or southwestern college teaching agricultural engineering. Has always been connected with colleges and college work. Age 25 and health excellent. PW-303

AGRICULTURAL ENGINEER with six years' experience as an engineer in soil conservation work, familiar with soil surveying and land appraisal, and some experience in farm management, farm reared, and with degree of bachelor of science in agricultural engineering, desires a position in farm machinery design, farm management, or soil conservation work. Will go anywhere. Age 32. PW-304